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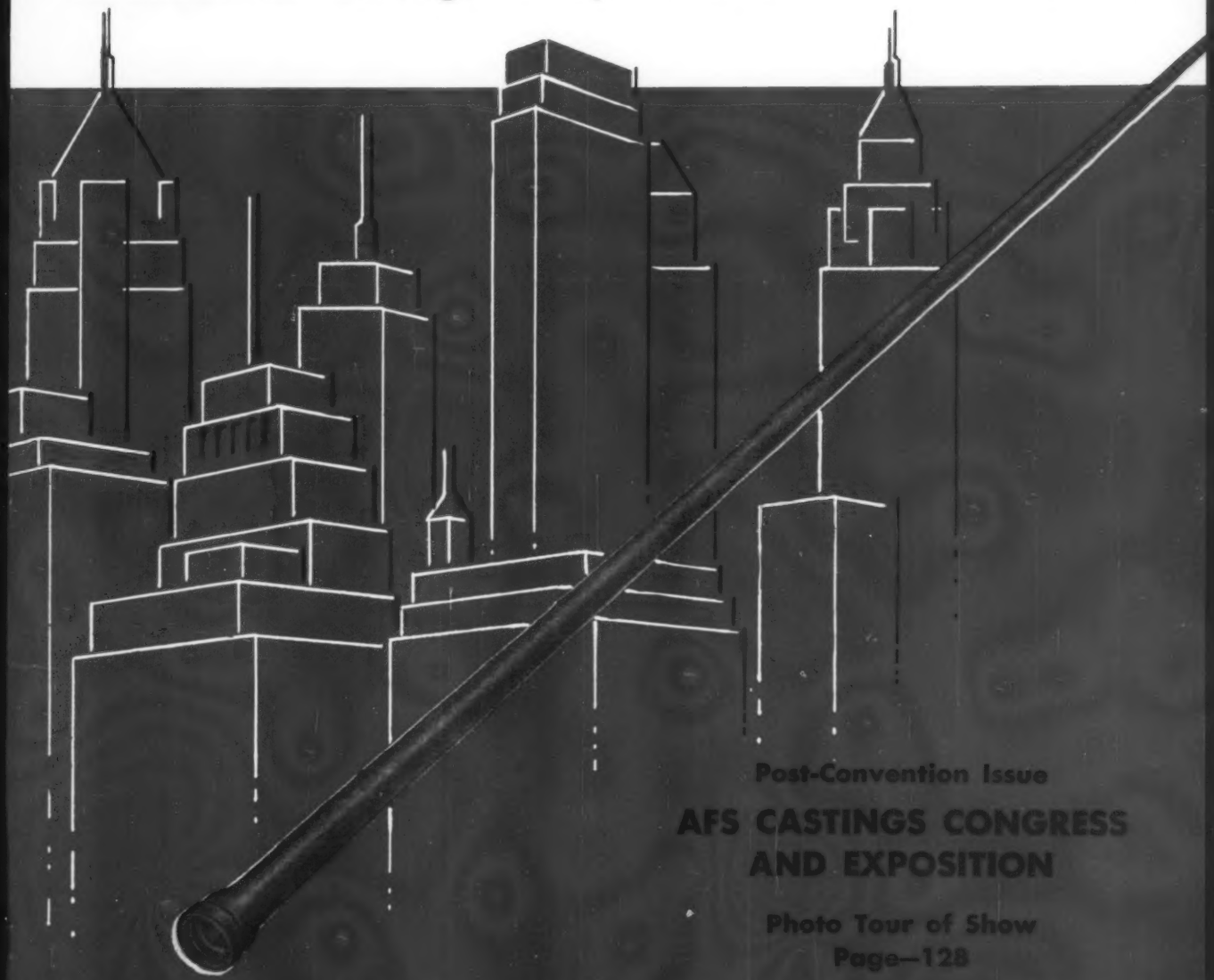

Post-Convention Issue

AFS CASTINGS CONGRESS AND EXPOSITION

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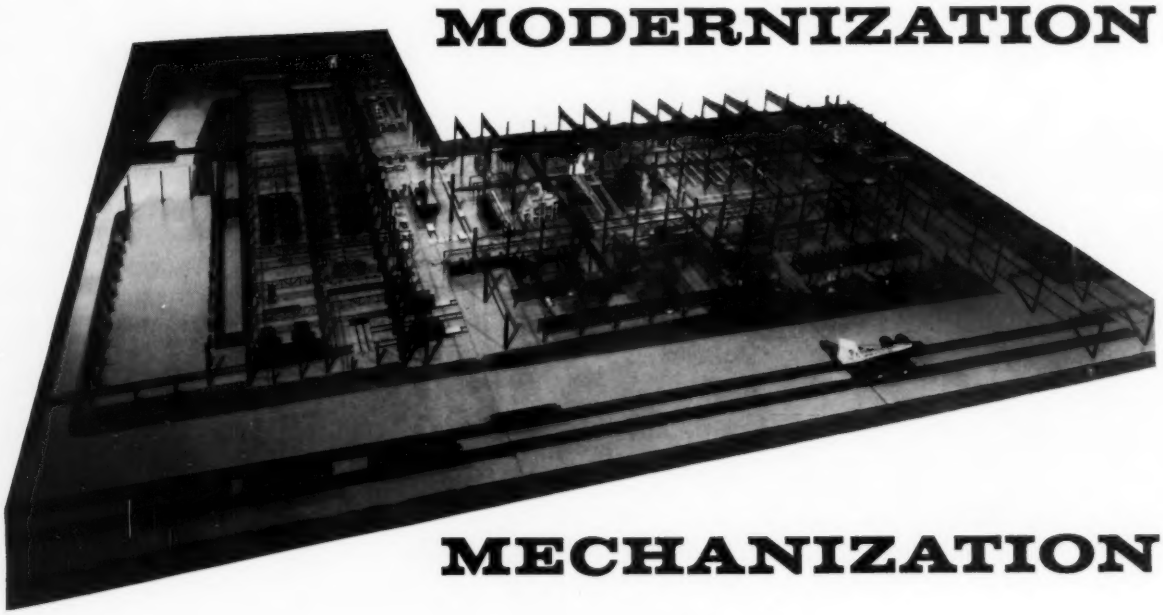
modern castings

JUNE 1960

A timely message for foundry managements

MODERNIZATION



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Circle No. 121, Page 165

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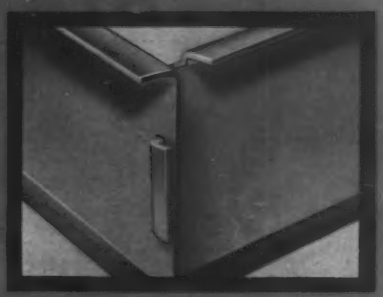

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FROM TOM BARLOW

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* Cupoline 77 is the new, low-rebound, fast-setting gun patch that is reducing patching costs for foundries all over the country. (Even people who used to make their own are changing to 77.)

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June 1960 Vol. 37, No. 6

modern castings

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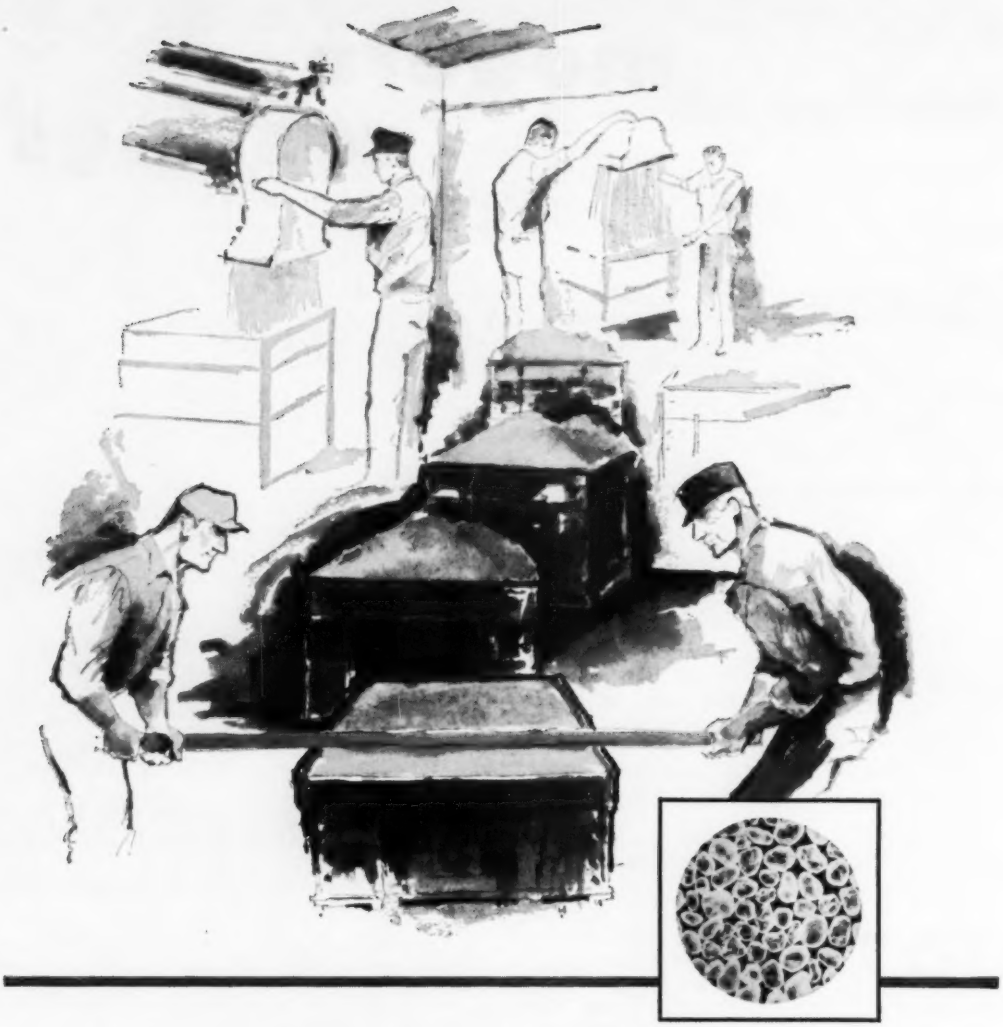

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Let's look at...

WHERE MARKETS ARE BORN

N. J. Dunbeck

THE ELECTION of N. J. Dunbeck as president of the American Foundrymen's Society is indeed a fortuitous event. He brings to his new post a unique perspective: an outstanding technical background, proved leadership within his own company, International Minerals and Chemical Corporation, and an acute awareness of our industry's product and marketing needs.

Significantly, Mr. Dunbeck will head a talented all-industry team—the AFS board of directors. This group has depth, breadth, and know-how. It represents every phase of metalcasting.

All this adds up to the fact that in AFS are the means to stimulate tremendously the types of technology which expand the markets of today, create the new markets of tomorrow. Each one of us knows that it is in the plant and in the laboratory where salesworthy products and markets are *really* born!

Along this line, in this issue, I recommend for your special reading the following exclusive and timely reports:

—The New Technology ..... See page 29
—World-wide Roundup ..... See page 40
—Our June cover story ..... See page 172

And be sure to note the comments of William J Grede, pages 43 and 59. He dares each one of us to "have the courage to try the new—and to fail!" It's a challenge none of us can ignore. If we falter, we will be left behind by more alert and aggressive competitive industries.

Harold E. Green

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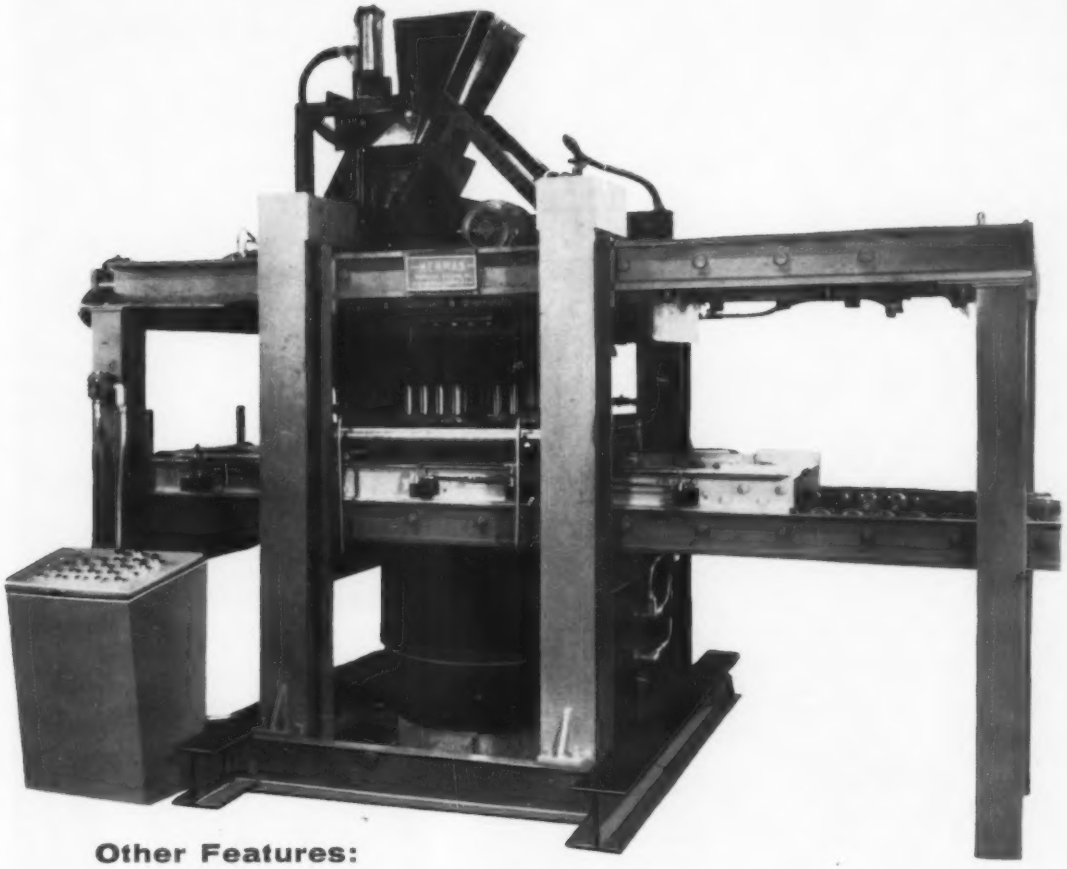

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Circle No. 135, Page 165

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ABCO ALUMINUM & BRASS WORKS, Houston, Texas, finds that PETRO BOND molding sands meet all requirements for precision castings. Pictured here is an aluminum dry air heater coil cast in PETRO BOND sand.

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PETRO BOND is available from foundry dealers everywhere. See opposite page for list of dealers.

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Circle No. 128, Page 165

Reader Opinions and Ideas

Hot Properties of Sand

I was quite impressed with the paper "Hot Properties of Molding Sand" by A. G. Johnston of Canada Iron Foundries, Ltd. The literature can certainly use such a concise summary of the hot property of prime importance. Particularly, it is desirable to show the rather unusual relationships which frequently exist between western and southern bentonite.

So many times, we make an assumption that when two clays are blended, they change each others' properties in some straight line function. In the case of western and southern bentonite, as shown by this paper, hot property relationships are a long way from being a straight line.

This provides foundrymen with an unusual degree of control if they recognize the direction they are moving. I believe one point might be emphasized on hot properties to further the objective of the author. Certainly he is attempting to give a practical or working relationship here. When we are working with practical considerations, however, it is important that we point out that the specimens tested are prepared under laboratory control and represent only the three ram specimen.

For example, the author states that at 2000 F, hot strengths of 100 pounds per square inch are adequate for most gray iron castings. In this I concur. However, we must be careful about the fact that there is a direct relationship between the hot strength and the ramming intensity. The three ram specimen as indicated by his figures and data provides the hot strength of 100 under many circumstances.

However, under conditions of molding, many foundries seldom reproduce a mold density equal to a three ram specimen. If we vary the ramming density as represented by variations in mold hardness, we find that hot strength can be effected almost as much by ramming as it is by changing clay. For example, the hot strength of 100 at 2000 F, as represented by a three ram specimen, could be increased with no changes whatsoever to 160 pounds or it could be dropped to 20 or 30 pounds merely by either over ramming or under ramming as compared to the laboratory specimen.

I believe it is for this reason that many foundries find that they cannot

operate on a laboratory property of 100 pounds. They have to develop a safety factor by going to a higher laboratory figure in order to make sure that under their conditions of softer ramming, they still have adequate hot strength left. This same situation applies to expansion and hot deformation. Of course, the soft ramming is in the right direction in expansion, but unfortunately, very much in the wrong direction on hot deformation.

A soft rammed specimen is hot brittle and as a result, it is frequently desirable to run the hot deformations as reported by the laboratory to unusually high figures to make sure that they are still adequate under conditions of inadequate ramming.

T. E. BARLOW
Sales Manager, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill.

A Real Contribution!

The fine paper entitled, "Hot Properties of Molding Sand" by Mr. A. G. Johnston, appearing in the February MODERN CASTINGS represents a real contribution to foundry literature.

A few details I would like to take up, however, near the top of page 39 on the subject of expansion. Some statements are made to the effect that finer sands, a single screen sand or a double peak sand will expand more than a coarse sand or one of a broader grain distribution. Generally speaking, these statements are quite true; however, investigations by the AFS Basic Concepts Committee have indicated that this is a rather complex study and that exceptions to these generalizations may occur.

It has been my observation that it was not generally practical to attempt to actually reduce sand expansion. But as Mr. Johnston suggests in his next topic, minimize or counteract the effects of expansion by means of hot deformation control. It is quite easy to secure adequate deformation at temperatures above 1600 F; it is more difficult but extremely important to provide adequate hot deformation in the high expansion range of 1000 to 1500 F.

It also is very true that excessive fines and silt tend to decrease hot deformation and impart scabbing tendencies to the sand. Any type of true colloidal mineral clay (as distinct from silt) will help hot deformation.

Green deformation of a clay bonded sand tends to increase with increased moisture almost as a straight line function. Perhaps not so well

smoother surfaces with

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ABCO ALUMINUM & BRASS WORKS, Houston, Texas, cast this heater coil from manganese bronze, using PETRO BOND sand. Note the smooth surface, the faithful pattern reproduction, the absence of porosity.

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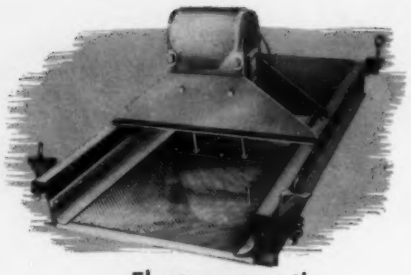

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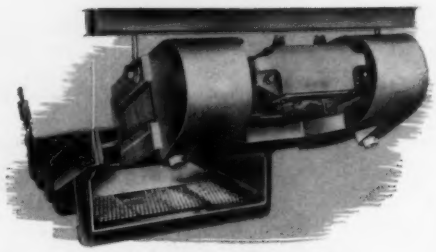

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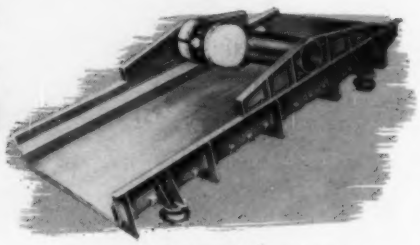

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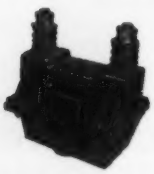

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Circle No. 129, Page 165

appreciated is the fact that hot deformation tends to decrease with an increasing moisture content. The lowest practical moisture level in any clay bonded sand is preferred, as Mr. Johnston suggests, for best high temperature performance. Low moisture also insures flowability—the easiest ramming to achieve high mold hardness. This in turn produces minimum mold wall movement and the best casting finish.

Mr. Johnston has done a commendable job in this presentation. The only thing I might add basically is that I like the results obtained with high clay content, low moisture, hard rammed molding sands.

VICTOR ROWELL
Manager, New Products, Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland.

To The Point

A. G. Johnston's article on "Hot Properties of Molding Sand" is well written, concise, and to the point. However, I do not agree with all his premises and tests. Unfortunately, I cannot back my arguments with data since all my data is at Deere & Co. and National Malleable & Steel Castings Co. Hence, I must quote from memory.

In the first place, Mr. Johnston does not say anything about the type of sand, source, grain fineness, etc. He does talk about fine and coarse sand, two peak sand, grain distribution, and fines. In elevated temperature testing the source or type of sand and the fineness are equally important.

As I recall, when mixtures of western bentonite and southern bentonite or western bentonite and bonding clay or southern bentonite and bonding clay were tested at certain ratios, hot strengths at 2000 F were higher than obtained on any specific clay. Unfortunately, I do not recall what these ratios were.

Western bentonite reaches its maximum hot strength at 1875 F plus or minus 10 F. It actually is a point and not a curve. Hot strength comes up to this point very rapidly as the temperature increases. It also drops off from this maximum point very rapidly as the temperature increases above 1875 F. So, at 2000 F hot strength is well below its maximum.

For ideal sand expansion and hot deformation, use a sand mixture in which one equals and does not exceed the other. With this condition a minimum, practically no mold wall movement would be obtained, providing ramming, etc., were uniform. Also, expansion defects would be eliminated. This is very important in

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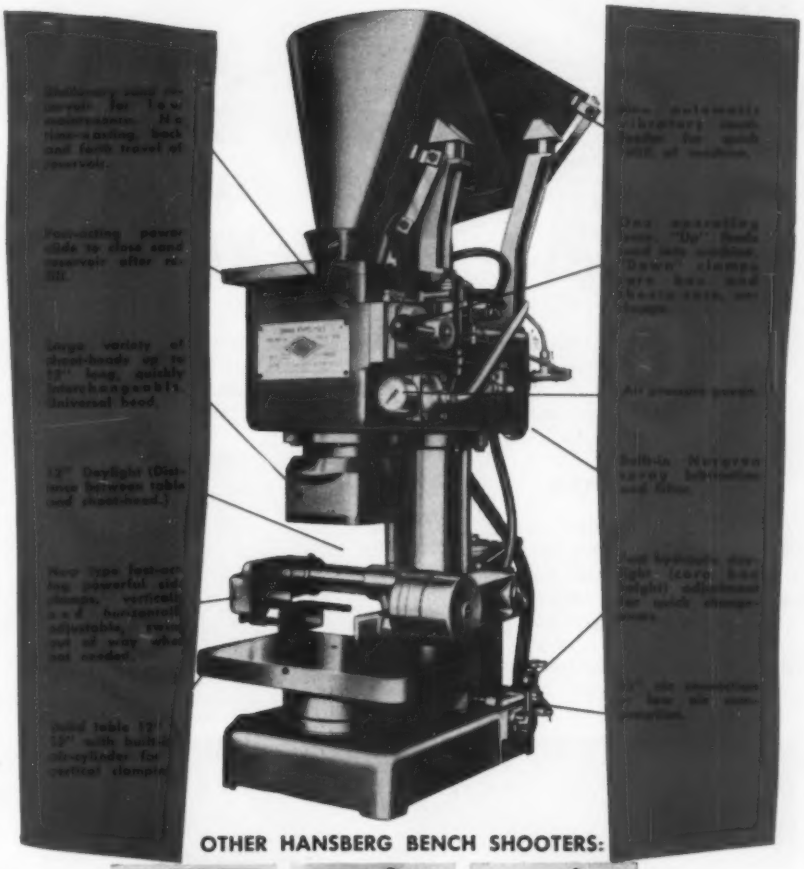
Increases Production

A large Chicago area foundry, using the model H 2½M, reports a saving of $200 per week, as compared with the results on same cores with earlier core-blower.



OTHER HANSBERG BENCH SHOOTERS:

1. **Model H-M Small Capacity Bench Model. New modern side clamps.**

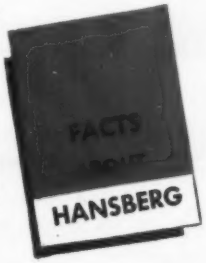
2. **Model No. H-1M 5 lbs. Capacity Bench Shooter with Hydraulic Core Box Height Adjustment. New modern side clamps.**

3. **Model No. H-2½M 8 lbs. Capacity Bench Shooter with Hydraulic Core Box Height Adjustment with Power Sand Slide. Standard Sand Hopper.**

With HANSBERG SHOOTERS

YOU CAN SAVE ON INITIAL COST • SAVE ON SET-UP TIME • SAVE ON CORE BOX WEAR • SAVE ON MAINTENANCE • SAVE ON COMPRESED AIR

SEND for "FACTS about HANSBERG SHOOTERS." The difference between core blowing and core shooting, why the SHOOTER is a "MUST" for the CO_2 Process, etc.



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Circle No. 130, Page 165

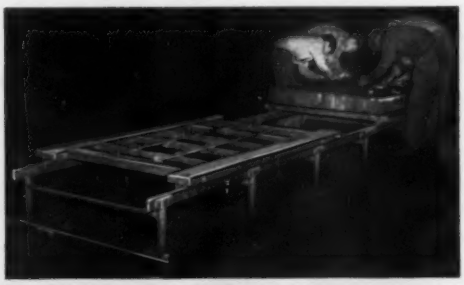
NOMAD CONVEYOR SYSTEMS

HANDLE LARGE, HEAVY MOLDS EFFICIENTLY!

Five lines of Nomad Single Track Conveyor carry 50″ x 66″ molds weighing approximately 4000 lbs. The molds ride on wheeled pallets over heavy-duty steel rails (¾″ x 3″) set 10″ above floor level. A transfer car distributes molds for storage and pouring to the five lines.

STURDY CONSTRUCTION

This 52″ x 80″ pallet is shown on track before the mold has been placed on it. It is fabricated of heavy steel sections equipped with Nomad No. 1200 Rollers — each roller having a load capacity of 1000 lbs.



Another view of the bay shows the five storage lines completely filled with molds.

Write Today for information on other types of conveyors and equipment designed for lighter or heavier loads.

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Designers and Manufacturers of Complete Conveyor Systems

NOMAD EQUIPMENT

Circle No. 131, Page 165

today's market for castings since so much stress is being put on dimensional accuracy of castings. Hence, exceedingly high hot deformation, or hot deformation exceeding expansion by a wide margin, is just as bad as high expansion.

E. C. ZIRZOW
Director of Foundry Service, Werner G. Smith, Inc., Cleveland.

Handling Costs Money

Thanks for your article in the April issue of MODERN CASTINGS on the problems of materials handling. A survey of the tremendous loads humped and distances traversed in foundries nowadays, even the 'modern' ones, is most apt. This collection of data may jerk foundry engineers out of their happy-carry lucky state and make them more aware that handling costs money.

Unfortunately, the little people, who put holes in the best of castings, seem to have crept into your tables and the sums given simply do not correlate. For instance, in Table 1 you give the total vertical distance as 1439 feet, the correct total being 1553 feet. You also mention that about 700 hp are required to make one ton of castings; that, of course, is not true. This power is required to make whatever the total output of the foundry is (which unfortunately is not stated).

However, I should like to stress that these comments are rather picayune and detract but little from the great value of the paper.

GEORGE MARTIN
Chief Metallurgist, Industrial Research Laboratories, Div. of Honolulu Oil Corp., Los Angeles, Calif.

Editor's Note: *In rechecking my arithmetic I see that my total vertical footage was incorrect. I must have started to get a bit punchy about that time. Believe it or not, I had twenty-five typewritten pages of weight and distance measurements!*

Your point on the horsepower is well taken. Although I believe I hedged enough on the title of Table 2 to weasel out if I had to. As I interpret it, 700 hp was the total (rating) of the mechanical equipment (involved) in making the ton.

Investment Casting Course

A course designed to provide technical and operating personnel in the precision casting field with fundamentals concerning investment materials will be sponsored by the Investment Casting Institute, June 14-17, at Alfred University, Alfred, N.Y.

VOLCLAY BENTONITE

..... NEWSLETTER No. 68 .....

REPORTING NEWS AND DEVELOPMENTS IN THE FOUNDRY USE OF BENTONITE

MOLD EROSION

Erosion of sand by metal appears as rough spots and excess metal at the places where defects occur.

Sand inclusions may appear at other parts of the casting.

Usually, erosion occurs directly in front of the gate area, or at sections of the mold where there is a nozzle effect of the metal flow.

Illustration of erosion defect.

The illustration is typical of a sand casting where poor thermal properties exist.

There are many causes for such irregular and poor thermal properties.

The principal offenders are listed:

1)—Dry, hot and retained strength of the bond used are low.

2)—High water gives false data, as the dry strength may be high but there is no hot, or retained strength.

3)—Certain cellulose additives destroy hot and retained strength rapidly.

4)—Any molding sand that contains a preponderance of high cellulose, combined with high moisture content, is difficult to ram; therefore, it erodes easily.

5)—Certain cellulose materials suppress fired strengths of good western bentonites.

6)—Loss in density is one measurement of the sand mixture that informs the foundryman erosion could occur. If the density continues to decrease, danger is ahead.

Place your insurance in proven products; use VOLCLAY western bentonite to insure hot and retained properties, use CELLFLO as the cellulose additive, if required.

(WRITE FOR NEWSLETTERS NOS. 7, 10, 16, AND 43 FOR FURTHER DATA)

AMERICAN COLLOID COMPANY

SKOKIE, ILLINOIS • PRODUCERS OF VOLCLAY AND PANTHER CREEK BENTONITE

Circle No. 132, Page 165

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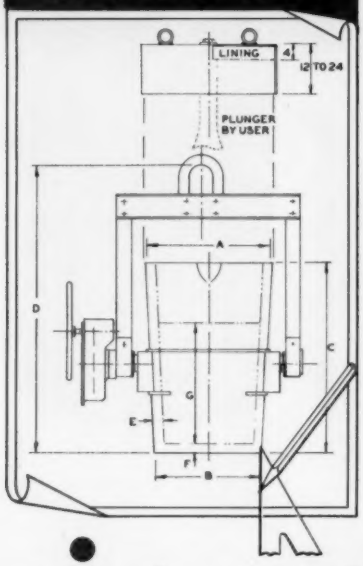
designed
to lower costs
of ductile iron



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Shielded reaction cuts heat loss, reduces slag formation, and eliminates need for costly fume removal systems. Capacities to 6000 lbs. Write for data sheets 52759.

Industrial
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271 OHIO ST., MINSTER, OHIO
Circle No. 133, Page 165

DIETRICH'S CORNER

What Price Engineering Education?

by H. F. DIETRICH

The current trend in engineering education is certainly heading the foundry industry toward a loss in business. We have been so interested in training metalcasting personnel that we have lost sight of what's happening to general engineering education. If the present trend continues, the "foundry personnel problem" will take care of itself . . . we won't *need* many foundrymen.

More and more colleges and universities seem to be eliminating shop courses, the so-called "hardware" courses. And foundry shop courses fall perfectly into this category. Many engineers graduated today have never seen a molding process. Many teachers of shop practice in secondary schools have never seen metals cast because the colleges and universities they attended did not have an operating foundry.

This is not entirely the fault of higher education faculties. Although our education system does have great academic freedom, it is also influenced by pressure groups. The most vocal of these groups today are yelling for *scientists*. To meet this pressure, some colleges seem to be trying to roll out a species of egghead whose primary function is to sit in a cubicle and dream.

Now, I'll grant that we need eggheads. We need the dreamers who will emerge from college steeped in theory, highly educated in math and science, and capable of revolutionary discoveries that will make the world a better (?) place. In spite of what the students' mothers think of them, those of us who must train these young people believe that only one of every thousand students entering engineering college can absorb such education; of the other 999, perhaps five out of every hundred will ever handle experimental work. What happens to the other 949? They become the engineers who go into industry with little or no experience in manufacturing processes. Yet in their hands is entrusted full responsibility for product design and production control.

Necessarily, many of these graduate engineers will become the potential buyers of foundry products. Without a knowledge among these engineers of manufacturing processes (including metalcasting), the foundry industry will certainly suffer by their buying decisions.

Now I agree that the engineer need not be taught the skill of a mechanic, but he should know what processes are essential to industry —and why. To operate a business efficiently, he must know what manufacturing process best meets his needs. One laboratory demonstration will make more of an impression upon his learning than anything he will find between the covers of a book . . . or any motion picture he sleeps through.

To carry this current concept of an engineer to the ridiculous extreme would require a new species of man. He would have a large, expandable skull to hold all necessary theory. Because he would never use his hands, he would require only one finger—for pushing buttons. He should have a broad base upon which he could be firmly planted in upright position. Living in a two-dimensional world, he would have no need for stereoscopic vision or hearing. All he needs is one ear to hear questions and three eyes to read books that best suit his needs. Until such a man comes along, perhaps we should continue training our young men to live in the world of today.

Now the question is, shall our institutions of higher learning be operated primarily for the one in 1000, the five in 100 or the total 1000 capable of college level education? Unless the needs of industry are made known to the college accrediting boards, we will produce graduates over-educated in theory and under-educated in practice for industrial use. We will produce design engineers who have never seen metal cast, who can't read a blueprint, and who couldn't draw an idea if they had one. It is up to us. Unless we make our needs known to the educational system, the trend of current engineering education will result in loss of trained men for the foundry industry and in loss of business, too.

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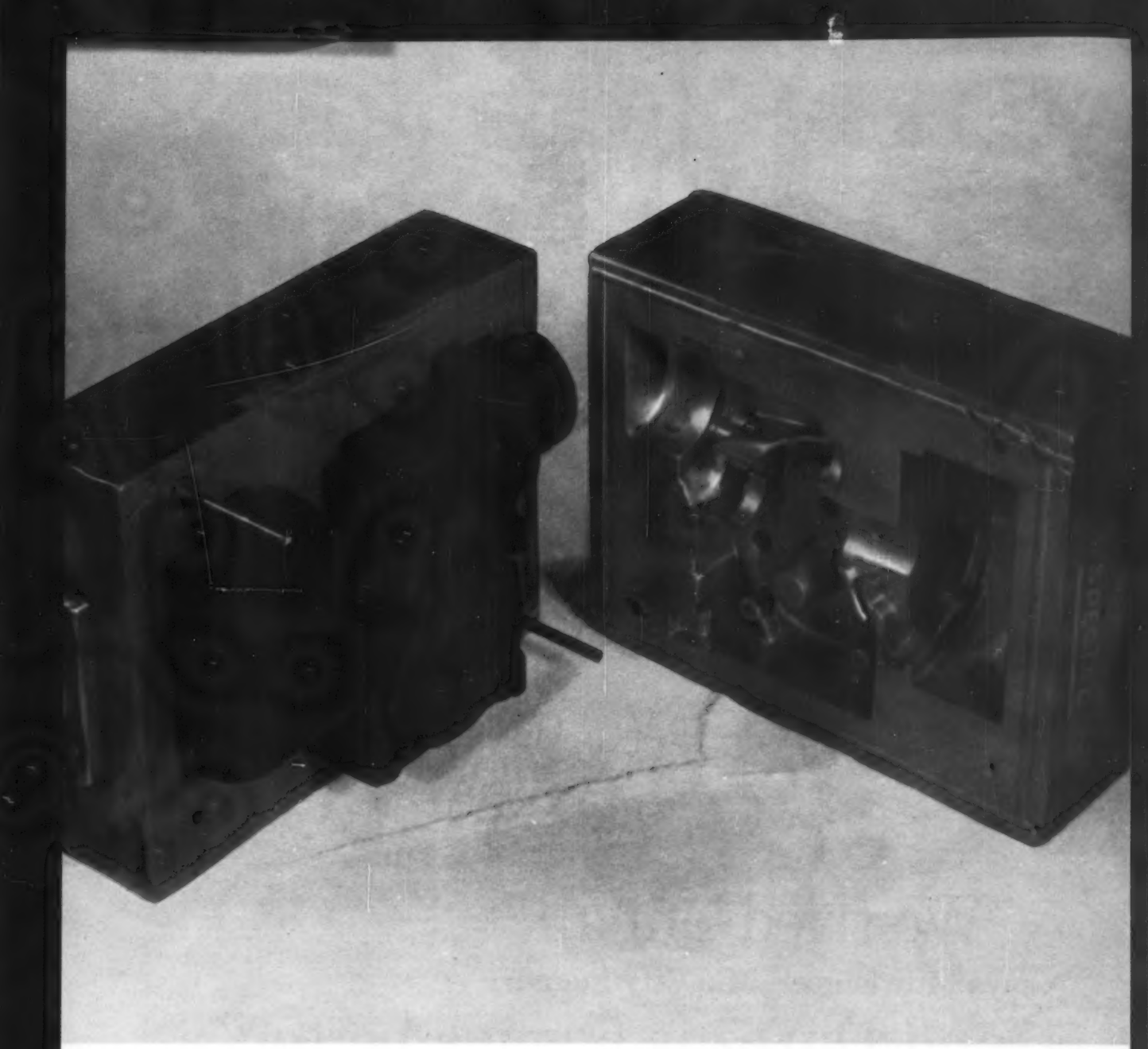

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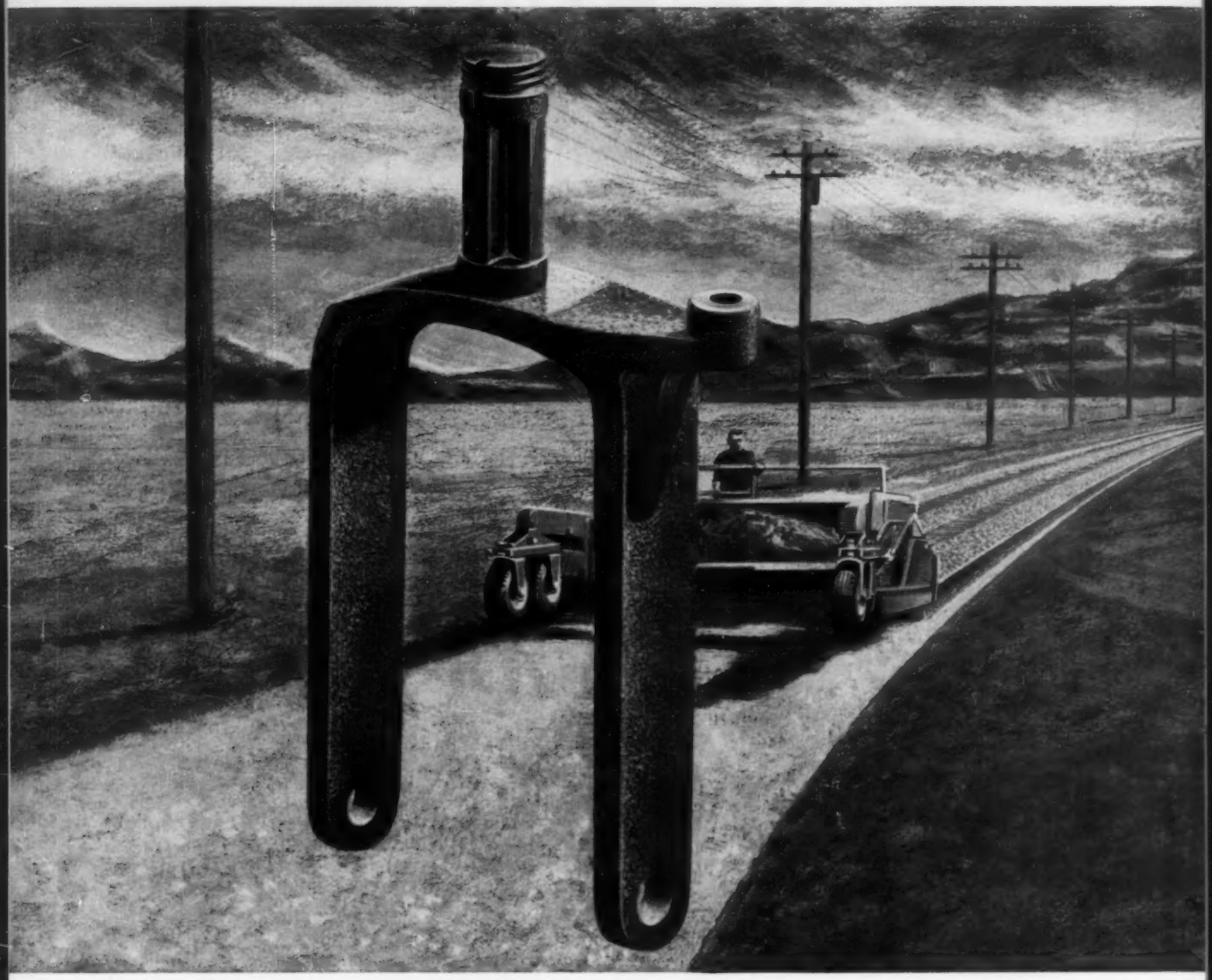
How the Foundry Industry Serves America . . . #6 of a Series



CAST IRON WHEEL FORK REPLACES WELDMENT . . . CUTS COST 29%

Rugged construction of every single part is vitally important in the manufacture of road building equipment.

Capable of spreading up to 400 tons of base materials per hour, the aggregate hopper of the 12-ton base paver, shown above, is supported and steered by front wheel forks. These must take a terrific pounding day after day, to assure maximum service life for the entire unit. Originally the forks were made from steel weldments. They were redesigned to high strength gray iron castings. This reduced manufacturing operations from nine to three, and cut fabricating costs by over 29%. This is just another example of how modern iron castings can solve many of the problems of industrial design and at the same time effect substantial manufacturing savings.

For the production of structurally sound iron castings, Hanna Furnace provides foundries with all regular grades of pig iron . . . foundry, malleable, Bessemer, intermediate low phosphorous, as well as HANNATITE® and Hanna Silvery.

Facts from the files of Gray Iron Founders' Society

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Circle No. 137, Page 165

In the interest of the American foundry industry, this ad (see opposite page) will also appear in

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If you would like to have reprints of this ad to mail to your customers and prospects, let us know. Reprints will have no Hanna product message or signature, but will be imprinted with your firm name and address. Absolutely no obligation. To order your reprints, fill in and mail the coupon below.

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TRENDS IN EDUCATION

"GETTING THROUGH"

by RALPH BETTERLEY

To those of you who are parents, I'm sure you have on several occasions attempted to vociferously instruct your child on some specific point of safety, behavior, or what-have-you, only to receive in return a question completely remote from the point you are attempting to make. I cite, for example, the school principal who, after lecturing to an eighth-grade graduating class, asked "Are there any questions?" He received this response from a little chap in the front row, "Yes, Mr. Born, how do you fold the handkerchief in your pocket so it makes four points?"

I realize the above story sounds trite and elementary; however, it is representative of the "goofs" and "snafoos" existing in industry and the business world today because of poor communications. The only difference is that the uninhibited youngster will say: "You're not 'getting through' . . . you're not 'putting it across' . . . I don't understand you" . . . or, at the worst extreme, "I'm not listening to you." Industry might be better off if this inherent weakness could be exposed; however, it never seems to happen so business goes on with poor communications costing thousands, perhaps millions of dollars, annually.

The listener is not the complete answer, for we must not forget that communication, like sound, is a three component system . . . encompassing a sender, carrier and a receiver. All must function equally well, regardless of form, if good communication is to exist. It follows, therefore, that the spoken word . . . the drawing . . . the picture or live demonstration, can all fail or be distorted if one of the components is weak or non-existent.

O.K. then, let's admit that our industrial communications leave something to be desired. In far too many cases we are not "getting through" or "putting it across" when conducting our operations and promoting our products. Written or spoken material should be clear-cut, complete, yet concise and accurate in direction.

It should not be overlooked that good communication is a two-way avenue between transmitter and receiver. It exists in the most-effective form when understanding is exchanged back and forth, until each person sees the picture in the other person's mind. When giving important instructions to supervisors, foremen or other key-personnel, why not occasionally have them repeat back to you their interpretation of your instructions? You might be surprised. According to some surveys, a 60 per cent understanding of written instructions is considered to be about the best one can expect, notwithstanding that in this form re-reading and studying are possible. It is obvious, therefore, that "one-shot" verbal instructions given under tension, noise and pressure have little chance of reaching this efficiency.

Decisions, plans, policies and controls are all executed through people to accomplish the end result. The successful leadership of top management can only be realized through effective communication to other people. *It cannot be otherwise.*

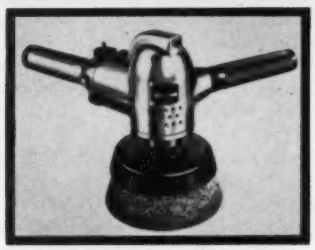
Analyzing your communications, you may find one of the three components weaker than the others. If we could all improve our listening, thousands of dollars of industrial effort could be saved. Have you ever wondered, when telling a "story" to two cronies, *are they really listening* —or are they planning the "one" they want to tell next? Can your communications be improved? How about a session on this topic with key personnel? Here are two movies* which would help your meeting: "Production 5118" on communications in general (now available) and a new film on *listening* entitled, "A Message to No One" (available August 15).

Communications has and will continue to plague the business world. Therefore, foundry management should take a hard look at their own techniques of "getting through." The last lyrics to the old song "Lazy Bones" clearly indicate the problem . . . "looky heah, neva heard one word ah said."

---

* Films are available rental-free from the Champion Paper & Fibre Co., 30 N. LaSalle St., Chicago, or through Modern Talking Pictures, 216 E. Superior St., Chicago.

AIRETOOL GRINDERS speed metal removal... cut costs!



Available with muffler which does not reduce power, speed

Airetool's job-proven, high-speed, pneumatic grinders cut time on tough metal removal jobs. Airetool grinders are job-fitted, too, with two vertical and two horizontal models for easy handling under varying job conditions. Vertical models use 6 and 8 inch wheels and horizontals 6 inch wheel and 7, 8 and 9 inch disc wheels. Airetool also makes heavy duty small wheel grinders for dies, castings and patterns and midget die grinders for intricate precision grinding. Write for Catalog 67.

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"Sermons in Stones" ...Lessons in Bars

by HERBERT J. WEBER

Most of us have heard the Shakespearean phrase: "Sermons in stones," but how many are aware of the fact that there are lessons in bars. Many of us have skimmed a ladle of metal with a skimming bar and noticed that the working end of the bar becomes red hot yet the handle remains cold.

That's because the bar is made of steel. But try to skim with an aluminum bar and you'll probably get burnt.

Why this difference? Because the thermal conductivity of aluminum increases with increasing temperature while in contrast iron's conductivity decreases with rising temperature.

There is another important difference. Hot iron will become red giving a visual warning of temperature; aluminum will not. That's because aluminum has a low emissivity and hence a low radiation energy in the form of light, whereas iron has a high emissivity.

Aluminum is a good reflector of radiation; iron is a good absorber. If you place a sheet of aluminum and sheet of iron side by side in the sun, the back side of the aluminum will be cool but that of the iron will be hot. Aluminum is a better conductor of heat but a poorer absorber of heat than is iron.

This leads us to consider other properties of aluminum which have a direct relationship to safety.

The specific heat of aluminum is 0.21 Btu per pound per degree F; that of iron is 0.15 Btu. This means that a pound of aluminum at 500 F will contain 10,500 Btu; whereas a pound of iron at the same temperature will contain only 7500 Btu.

The heat of fusion of aluminum is 170 Btu per pound; and that of iron only 125 Btu per pound. This means that pure iron on solidifying at 2795 F will give off 7/10 as many heat units as aluminum solidifying under 1211 F. Therefore other factors being equal, a splash of molten aluminum will cause a more severe burn than will molten iron.

Aluminum has a low viscosity index. Hence it is easier to get run outs and leaks with it than with molten iron, thus leading to unexpected burns.

When aluminum is heated to the melting point, it assumes a character quite different from the cold metal. Molten, it will react with all common metals. The reaction ranges from medium to violent.

It will explode in shallow pools of water; but the deeper the pool, the less chance of explosion. At 1240 F it will explode in 6 inches of water but not in 10 inches. At 1380 F, it will explode in 10 inches of water.

Aluminum has less tendency to explode in hot than in cold water. The geometry of the water container also affects the explosive tendency. It will explode more readily in narrow water containers than in wide ones.

An explosion can occur also by charging wet pig or scrap into a molten aluminum bath. Water immersed in the bath expands to over 4000 times the water volume in conversion to steam. Thus an ounce of water would expand to a volume exceeding 30 gallons. No wonder the explosions are so violent.

The lessons from the bar then are:

1) In the foundry assume every piece of aluminum scrap casting or pig is hot before touching it.
2) Be alert for run outs or leaks. Assume they will occur.
3) Don't charge any aluminum into a furnace unless *you* know it does not contain included moisture.
4) When handling molten metal, always wear safety goggles and protective leggings or spats. As much of the body as possible should be covered with normal-type clothing that is resistant to burning. It should fit closely at the neck, waist and sleeves. The sleeves should not be rolled up.

As to the sermon? A stone can't get hurt, but you can.

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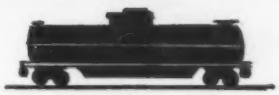

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Circle No. 139, Page 165

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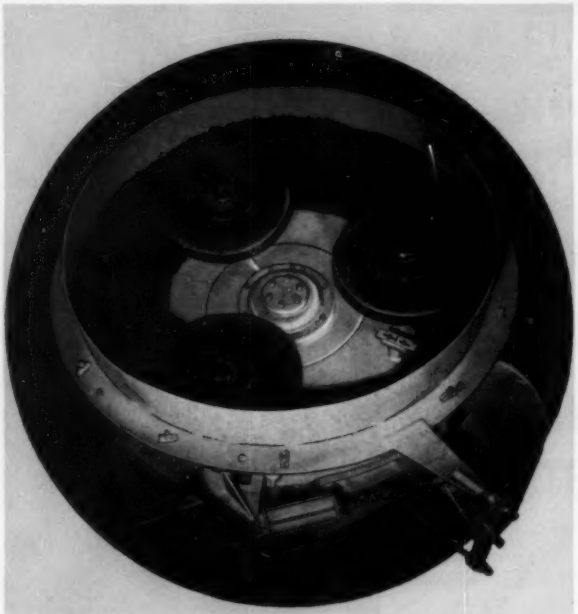


"AERATION AND COOLING IN THE MULLOR"

Our "slow" mixer had always required an external aerator . . . that meant an additional investment and additional maintenance, too. We saw that Speedmullor mulling in suspension actually provides more thorough aeration than could ever be accomplished by a separate aerator. Most foundries reported that their sand was up to 25% lighter in weight per cubic foot on discharge from a Speedmullor . . . that's real aeration.

Speedmullor Cooling offers a real advantage, too. We mull hot shakeout sand and it has to be cooled before use. With Speedmullor Cooling we can force cooling air right through the sand and accomplish real cooling *in* the mullor . . . that eliminates an expensive external cooling unit.

"REAL CAPACITY PLUS MAXIMUM MULLING"

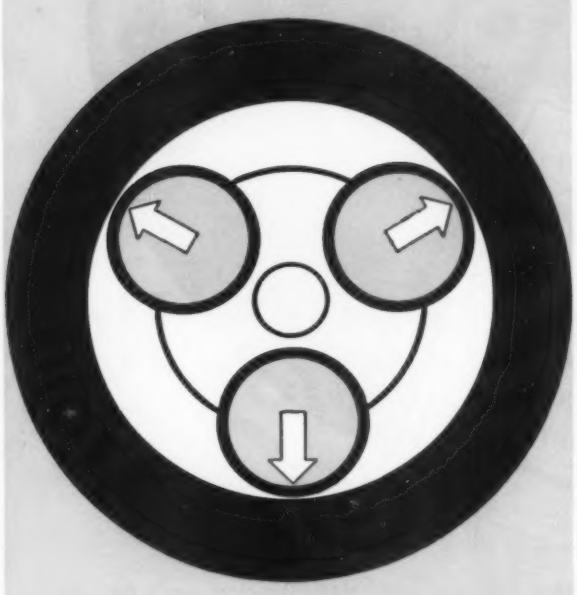
We found that there was no mystery to the output advantage of Speedmullors. We had known that mulling was merely the application of work energy to the sand mixture to obtain a squeezing and kneading, coating action. The work has to be applied as pressure over an area of sand. Speedmullors utilize centrifugal force to apply even greater pressure than the heavy mulling wheels of a "slow" mixer. Yet, the mulling wheels of a Model "80A" Speedmullor cover three times the area covered by the slow moving wheels of the largest conventional mixer. The result is over three times the mulling.

In our "slow" mixer there's a lot of slippage, too. Sometimes the big steel wheels just slide around instead of rotating. With Speedmullor rubber-to-rubber mulling, there can be no slippage . . . and there's better mulling with rubber, too.

Circle No. 140, Page 165

. . . that's why we bought SPEEDMULLOR*

Our mulled sand requirements had increased steadily, until our conventional "slow" muller just couldn't keep up, *and* provide the quality we needed, too. When the time came for its replacement, we figured we would have to install two new mullers. That's when we decided to investigate Speedmullors, although some of our "old timers," accustomed to "slow" mixing for so long, were hesitant. We thoroughly checked Speedmullor users on their performance and capacity, and that's when we really got interested.



"CENTRIFUGAL FORCE SPEEDS DISCHARGE"

The time required for discharge in our "slow" muller (25 to 35 seconds) had always seemed long and wasteful. There's no mulling accomplished during discharge and a slow discharge really cuts into capacity. The Speedmullor uses centrifugal force to discharge the sand, too . . . and it's really fast. A complete, thorough discharge requires only 7 to 11 seconds in the Speedmullor. Faster mulling and faster discharge add up to lower power cost . . . even with the more powerful Speedmullor. My car is more powerful today than was one thirty years ago, but it sure goes a lot farther on a gallon of gas.

"THERE'S NO MYSTERY TO MULLING"

We learned that Speedmullor mulling *fully* develops physical properties in mulling cycles less than one-third as long as in our conventional muller. With over three times as many batches per hour, the Speedmullor more than offsets the larger batch size of our conventional mixer. In fact, an "80A" Speedmullor provides more than 50% greater *hourly* capacity of fully mulled sand than the largest size conventional mixer . . . and would meet our capacity needs at lower cost.

***One of 863 foundries that have *replaced* conventional "slow" mixers with Speedmullors.**

902 foundries have placed repeat orders for Speedmullors. One single foundry has 39 Speedmullors in operation, and one single company has 72 Speedmullors in operation.

TODAY, MORE FOUNDRY SAND IS MULLED IN SPEEDMULLORS THAN IN ANY OTHER MULLERS

PROGRESSIVE FOUNDRIES LOOK TO
BEARDSLEY & PIPER
FOREMOST DEVELOPER OF FOUNDRY MACHINERY

FEMA

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Circle No. 140, Page 165

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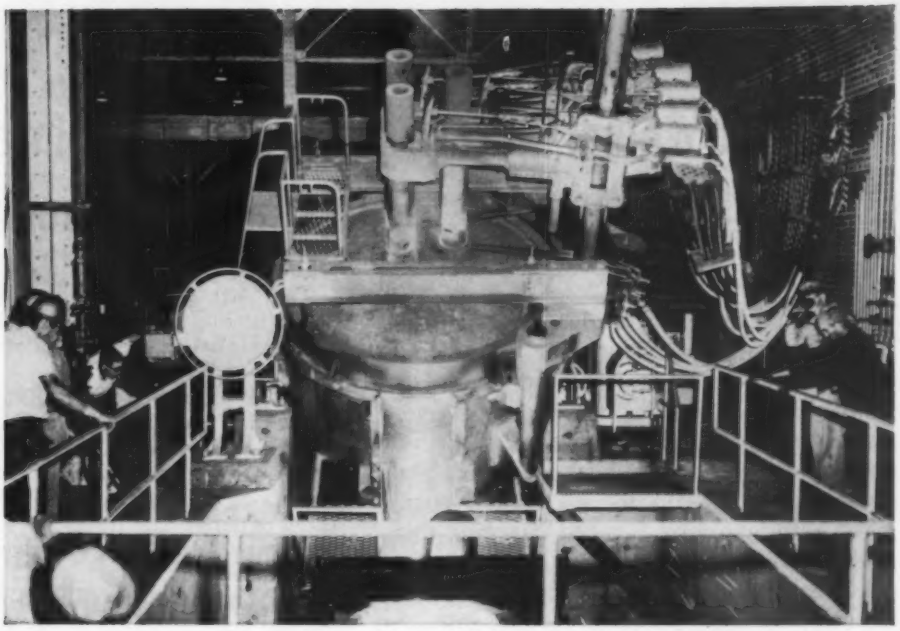
Circle No. 149, Page 165



When you melt or smelt

Lectromelt furnaces are available in types and sizes to suit all requirements — for melting steel for ingots and castings, and gray and malleable iron for castings... melting copper and nickel... producing pig iron, ferroalloys, calcium carbide, phosphorus, etc.... and smelting ores. For information, or a consultation regarding furnace requirements, write Lectromelt Furnace Division, McGraw-Edison Company, 316 32nd Street, Pittsburgh 30, Pennsylvania.

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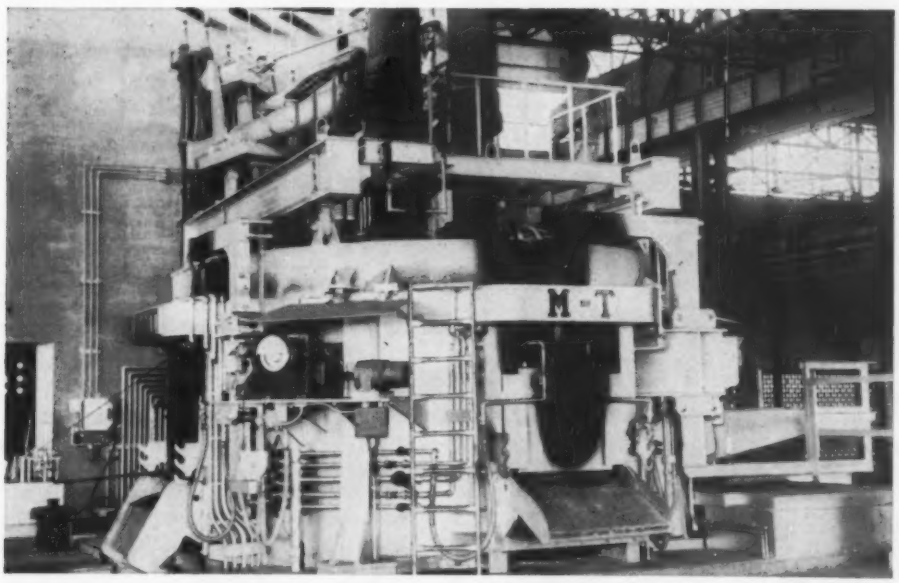


Lectromelt®

Circle No. 144, Page 165

New SPECIALIZED

Harbison-Walker Refractories meet the intensified conditions of today's aluminum melting furnaces

Within the last couple decades the production of aluminum metal in the United States has trebled and the number of its alloys has increased manyfold. Rapid evolutionary developments created the need for refractories to meet new conditions. The severity of corrosion, more destructive impact accompanying furnace charging and the necessity of avoiding contaminants for meeting rigid alloy specifications—these among other factors have become increasingly important.

Since the first commercial production of aluminum and its alloys, Harbison-Walker brands, primarily of alumina-silica and high-alumina compositions, have continued to fulfill the ever-growing demands. Through unceasing research several refractories, recently developed specifically for aluminum melting furnaces, possess definitely superior properties for maximum durability and best quality of metal.

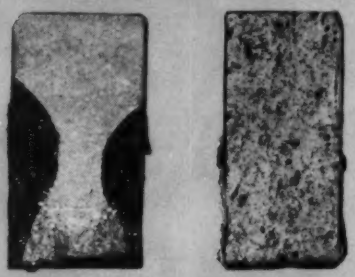
These unique refractories especially suited for aluminum melting furnaces are here briefly described.

CORAL-P (former name CORALITE 22-58) is a stabilized aluminum phosphate bonded brick containing approximately 85% alumina. It has exceedingly high strength and withstands greater impact and abrasion. Its resistance to wetting and penetration by the molten metal are properties of paramount importance. CORAL 24-59 is the hard-fired variation, having still higher mechanical strength.

CORAL (former name CORALITE 3-59) is a very hard-burned brick containing approximately 85% alumina. It is made with a special bond (patent pending) which contributes to its remarkable strength. As illustrated by the photograph showing results of the laboratory tests, it is exceedingly resistant to penetration and reaction with molten aluminum.

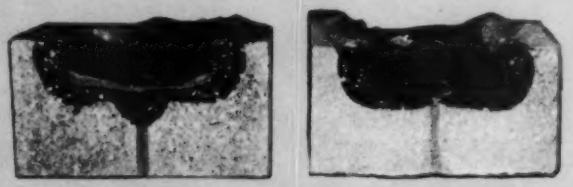
CORALBOND is a phosphate bonded high-alumina mortar developed specifically for use in aluminum melting furnaces. In this application it is preeminent for its durability and composition contributing to the avoidance of contaminants. Compared with many different kinds of mortars, CORALBOND is truly unique in its excellent performance in many aluminum furnaces.

ALUMINUM IMMERSION TEST



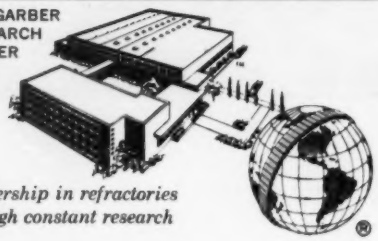
These brick, which were immersed in aluminum alloy at 1400°F. for nine days, show contrast in degree of penetration or wetting between a normal high alumina brick, left, and CORAL, right.

MORTAR JOINT TEST



Photograph of Laboratory "Cup Tests" with molten aluminum alloy, shows striking difference in resistance to penetration and corrosion between a widely-used air-setting bonding mortar at the left and the CORALBOND joint at the right. Among many mortars of widely different compositions, CORALBOND—as illustrated in this test—is unmatched.

THE GARBER RESEARCH CENTER



Leadership in refractories through constant research

HARBISON-WALKER REFRACTORIES COMPANY

AND SUBSIDIARIES — GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA

World's Most Complete Refractories Service

Circle No. 142, Page 163

Key Advances in Metalcasting Today

Here are the newest and most important trends in the industry. They are listed for you point-by-point — showing the way to metalcasting opportunities in the days just ahead.

MODERN CASTINGS asked 16 of the nation's leading foundrymen to give their views on these developments, based on the 104 papers presented at the Castings Congress in May.

This is a first-hand, exclusive interpretive report on foundry progress.

As told to JACK H. SCHAUM

NEW TECHNOLOGICAL advances in metalcasting are giving added impetus and strength to the industry. New market opportunities will result, sparked by many product and process innovations.

This is the consensus coming from the 64th Annual Castings Congress and Exposition, held last month in Philadelphia. Some 159 top experts in the nation told, in papers chosen especially for the occasion, what is new and important in metalcasting today. What they said is interpreted by 16 leading foundrymen mainly responsible for the program.

It's a panoramic view of what's in store for metalcasting in the days ahead!

1—MANAGEMENT DEVELOPMENT: *Watch foreign competition . . . unfair taxation . . . have the courage to fail.*

The Hoyt Memorial Lecture was the high-point of this year's program. W. J. Grede asked foundrymen pointblank "Where do we go from here?" Then he proceeded to tell them why they have been headed down and what they can do to point this trend up again. Foreign competition and taxation are two tough problems facing the foundry industry. Grede urged technical and research groups to have the courage to fail and never stop searching no matter how often they don't succeed.

2—PERMANENT MOLD AND DIE CASTING: *Aluminum automotive engines . . . low pressure permanent mold casting . . . ultra-high pressure die casting . . . German grain refining techniques.*

Aluminum engines are news. And in keeping was D. J. Flynn's paper describing the unique Chevrolet aluminum foundry operations. Here, parts for the Corvair aluminum engine are made by die casting and a special low pressure permanent mold process. The latter is the first large volume installation in the United States.

The process originated at Alumasc, Ltd. in England and is described completely in another Congress paper by E. C. Lewis. He tells how to cast aluminum holloware, rain-water goods, barrels, furniture, and textile loom components. Technique expels molten aluminum from sealed iron crucible up through a refractory, coated iron tube into the base of permanent mold.

Progress in the opposite direction—ultra-high pressure (100,000 psi) die casting—is underway at Doehler Jarvis. Their fundamental work

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6—Victor Rowell
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Federal Foundry Supply Div.
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7—Richard L. Olson
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9—James Thomson
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10—S. Lipson
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11—B. L. Bevis
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12—H. E. Henderson
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14—W. K. Bock
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15—L. R. Jenkins
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16—Ken Smith
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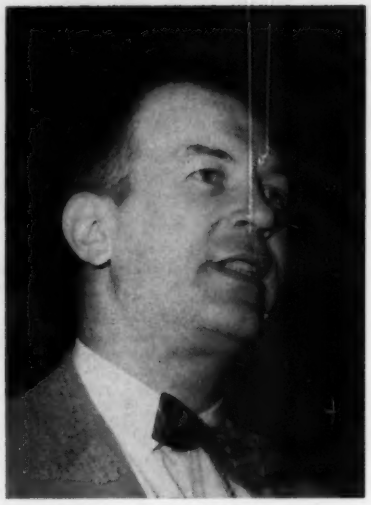


"Papers this year followed a trend aimed at better understanding of the fundamentals of sand behavior."—Victor Rowell

reports significant gains in mechanical properties.

Severe service requirements for aluminum engines are challenging metallurgy ingenuity. Capabilities of new silicon alloys were announced. The tough problem of grain refining high silicon alloys has been licked in Germany. K. Schneider disclosed German practices involving phosphorous bearing nucleants, sodium, calcium and chlorides of carbon.

3 – INDUSTRIAL ENGINEERING & COSTS: *Job evaluation . . . sensitive cost controls . . . incentive programs.*

The rapid advance of the foundry industry relative to new techniques and facilities requires a corresponding and parallel advance in administrative practices if full value is to be received in the future. The three "M's"—men, machines and materials—are being further coordinated by technology and mechanization.

The exciting and bold trend of the foundry industry toward increased output through mechanization and technology must not neglect the manpower element. A paper on "Job Evaluation—Asset or Liability" will help executives determine feasability of using the job evaluation tool in classifying the manpower factor.

Another paper describes a proven system for controlling costs of foundry operations. Recognized are the basic cost-generating areas and the best psychological approach to handling the people involved. The net result is an extremely effective, flexible, yet sensitive cost control system.

Over two hundred foundries were surveyed by questionnaire to learn of their incentive programs. A summary report recognizes patterns of similarity and proven advantages to assist management in future function in improving administrative practices and procedures.

4 – DUCTILE IRON: *Make riserless castings . . . save 40 per cent with ladle plunging.*

Casting Congress papers emphasized foundry practice and control required to produce sound castings of suitable quality.

Among unusual revelations was the new found ability to produce large ductile iron castings without risers. Chemistry must be properly controlled and mold must resist dilation under influence of metal pressure. Speakers enumerated effects of chemistry, mold materials, pouring temperatures and rates, metal cleansing, and fluid flow on ability to produce sound castings.

A revolutionary way for adding magnesium to molten iron is the "plunging" method. One of the papers described its suitability to large volume repetitive operations. As much as 40 per cent savings in alloy additions are possible compared to previous practices.

Quick, accurate metal quality assessment can now be made by a combination of metallographic, chemical, impact, transverse, and hardness tests —as revealed in one of the Ductile Iron Division papers.

5 – BRASS & BRONZE: *Molybdenum and tungsten carbide added to copper . . . columbium in cupro-nickel alloys.*

This important segment of the met-

"New ladle plunging technique is saving as much as 40 per cent in alloy additions when making ductile iron."—David Matter

"Four new patternmaking processes—nickel carbonyl, electroforming, Shaw and sprayed epoxy —have resulted in pattern equipment attaining production standards never before achieved."—Richard L. Olson

alcasting industry displayed a renaissance of interest in improving materials that will better meet today's more stringent technical requirements.

Imaginative research was displayed in papers which revealed: 1) the successful combining of insoluble refractory metals (molybdenum and tungsten carbide) with copper; 2) the use of silicon and columbium in cupronickel alloys to produce excellent mechanical properties in heavy sections; and 3) an aluminum-nickel-manganese bronze with superior properties. An awareness of understanding and improving current materials and techniques was displayed in the areas of shell molding, degassing bronze, fluidity, gating, risering, and chilling.

Undoubtedly, the wide range of subjects represented in the 1960 program signifies a new vitality in the industry. The future for brass and bronze castings is real and bright.

6 – SAND: *Russian foundry practices . . . parashrinkage–a new theory . . . 12 guides to identifying and curing casting defects.*

Russian foundry production techniques, outlined by Dr. Ylian Nekhendzi, were presented in his absence by D. C. Williams at the Sand Division Dinner. A detailed summary appears in this issue. Most papers this year followed a trend aimed at a better understanding of the fundamentals of sand behavior.

Work at Northwestern University on heat transfer through sand should remove much misunderstanding that has been prevalent. Below 1100 F, heat flows only by conductivity which decreases with increasing temperature. Above 1500 F, conductivity increases with temperature because of radiative heat flow.

A new theory involving parashrinkage phenomena is used to explain such defects as veining, metal penetration, scabbing, and hot tearing.

All the program was not theory. In one paper you can find 12 separate guides which identify casting defects, explain the cause, tell how to correct, and proper changes to make in sand mix. This practical guide belongs in every foundry quality control department. Apply this knowledge, and casting losses should tumble.

7 – PATTERNMAKING: *Four new processes–nickel carbonyl, electroforming, Shaw, and sprayed epoxy.*

This year's well balanced Congress program describes four important advances in patternmaking techniques: 1) Nickel carbonyl process; 2) Electroforming process; 3) Shaw process; and 4) Sprayed epoxy resin. These new processes can reproduce from a wood pattern or model, exact duplicates in nickel, copper, iron, steel, and high strength plastics. As a result, the pattern equipment can meet dimension, surface finish, and production standards heretofore never achieved. The competitive status of metalcastings is closely tied to the quality and economy of the pattern equipment required. These four new processes will do their job in keeping castings constantly competitive.

8 – STEEL: *Casting steel in shell molds . . . improved impact properties . . . use of oxygen to increase melting capacity.*

Non-metallic macro-inclusions, a casting defect which has plagued steel foundrymen for years, has at last been exhaustively investigated under the auspices of the Steel Division Research Committee. Progress Reports presented at the Castings Congress indicate a break-through in this work is imminent.

Shell molding has produced special problems for the steel foundryman. A paper presented on this subject shows that surface defects in shell molded, mild steel castings are primarily caused by the oxygen in the phenol-formaldehyde shell resin; practical cures for the problem were suggested.

Recent accelerated interest in lower impact transition wrought steels finds the casting industry concerned with the same properties in cast steel. The effects of nickel, manganese, section size and deoxidation practice on 0.30 per cent carbon steel were presented in a paper, "Impact Resistance of Nickel-Manganese Cast Steel".

Small steel foundries were shown a lost cost method of increasing their melting capacity without major capital improvements in a paper describing "The Use of Oxygen Gas Burner Equipment for Scrap Melt Down in the Arc Furnace".

Another paper discusses the equipment and methods which must be employed by a stainless steel foundry to obtain a reproducible practice that will insure good composition control of a combined addition of vanadium, silicon, titanium, aluminum, boron, and iron in avoiding the troublesome problem of hot-shortness frequently

"Economic foundry operation is not startling, earth shaking or glamorous."—B. L. Bevis

"A significant revolution in steel melting practices involves the use of calcium to reduce sulphur to the very low level of 0.001 per cent."—John F. Wallace

encountered in making Alloy 20, stainless steel castings.

9 – PLANT & PLANT EQUIPMENT: *Cold, warm, and hot process for coating sands.*

Probably the most significant recent improvement in shell mold and core sand practices has been the switch over to coated sands. In keeping with this trend, the Plant & Plant Equipment Committee arranged for a discussion of the various coating processes—cold, warm, and hot. Now each foundry can select the technique best suited to the type of castings and production needs involved.

10 – LIGHT METALS: *Premium quality castings . . . design flexibility.*

Perhaps the most significant trend relating to new light metals technology today is the growing awareness of the importance of metallurgical quality in castings. Four of the Congress papers were directly concerned with the characteristics of castings produced to premium quality standards.

These studies are making designers aware that castings offer a means for greatly reducing the number of design concessions normally made for the sake of fabricability. This awareness would be of little benefit if the quality standards demanded by close design allowables necessary for modern machines could not be maintained.

This challenge is being met by the authors of these forward-looking Congress papers—which cover aluminum, magnesium, and titanium practices. It remains now for the operating foundrymen to assimilate these new principles and put them into commercial practice.

11 – EDUCATION: *How to evaluate fabrication methods.*

An outstanding talk by J. G. Frantzreb was aimed at telling foundrymen how to evaluate various methods of fabrication. Economic plant operation was attributed to day-in and day-out conscientious efforts of systematically doing a good job of measuring and recognizing all the factors which make a job more efficient. Then put them to proper use.

This subject reaches into the work habits and pocketbooks of every industrial operation. Sound manufacturing operations are earned by exacting engineering designs and applications blended with proper use of the best materials and manufacturing processes available.

This in turn is supported by a well rounded complement of trained personnel who can produce the product at a price the customer can pay.

12 – GRAY IRON: *Three major cupola developments . . . unlimited feeding distance of risers . . . electron microscope explains toughness.*

Three major developments in cupola design have gained wide acceptance. First, hot blast up to 1000 F is yielding desirable economies and composition control. Second, water cooled protruding tuyeres permit air blast to reach middle of coke bed, giving more efficient combustion, higher melting temperatures, and economies in coke and refractories. Third, water cooled melting zone allows melting with little or no refractory so basic slags are economical.

Research revealed that inoculated irons require more feed metal to overcome shrinkage due to mold wall movement than do uninoculated irons. Feeding distance of gray iron has been revealed as *infinite* if mold walls are rigid.

Other papers discussed important international testing standards, heat treatment for dimensional stability, machinability and wear resistance. With the aid of an electron microscope, it was discovered that epsilon carbide precipitates within martensite to give increased toughness to nickel-chromium white iron. The future holds the most for the foundrymen who put to use the 1960 Congress technology.

13 – FUNDAMENTAL PAPERS: *Precision casting ceramics . . . hot tearing . . . calcium reduces sulphur to 0.001 per cent.*

A detailed analysis of the preparation, properties, and behavior of the various ceramics employed for precision castings was set forth in one of the Congress papers. This treatise on molding materials was a valuable contribution to a rapidly advancing field that is assuming increased importance to the industry.

Another paper discussed the fundamentals of binary alloy hot tearing. The basic approach used provided the information required to solve many of the problems associated with this troublesome defect.

A significant revolution in steel melting practices involves the use of calcium in basic induction furnaces to reduce sulphur to the very low level of 0.001 per cent. As a result, me-

"The symposium on metal solidification focused attention on this fundamental science so important in controlling metalcasting structures."—W. K. Bock

"This year's technical program of the Malleable Division was planned to serve the interests of foundry operating personnel."—L. R. Jenkins

chanical properties of the steel are significantly boosted.

A symposium on metal solidification was jointly sponsored with the Heat Transfer Committee and is described in their report.

14 – Heat Transfer: *Symposium on solidification . . . air gap formation . . . analogue computer solves problems.*

The symposium on solidification, sponsored jointly with the Fundamental Papers Committee, brought together the principals involved in casting grain structure control. Applications of these principals to steel, iron, copper, and aluminum alloys are shown in such a way that immediate benefits became obvious to operating foundrymen. By focusing attention on the fundamental science of solidification, this symposium will have the immediate effect of better control of metalcasting structure and properties. Extension of this thinking will produce still better castings in the near future.

Permanent mold casters will find valuable data in the Henzel and Keverian paper on air gap formation between casting and mold. This problem will receive more attention in the future because an air gap seriously affects heat transfer from casting to mold. And cooling rate is a major influence on final casting properties.

Keller and Arant traced the solidification of a rolling mill roll in a chill mold. The principles laid down in this study may be extended and provide a new tool for a better understanding of solidification.

Many heat transfer problems defy direct measurement of temperature. Fortunately, the analogue computer built and demonstrated at the Congress by Dr. Paschkis is filling the breach in our instrumentation shortcomings.

15 – Malleable Iron: *Help for operating personnel . . . section size limitations are being extended by special alloys.*

This year's technical program was planned to serve the interests of foundry operating personnel. A shop course on melting methods also compared various raw materials on the basis of economy and quality control. A second shop course demonstrated the principles and techniques used in casting design and design improvement.

At a round table luncheon, malleable producers were told how they compare with European producers in methods and progress.

A panel discussion of top operating personnel in the malleable industry revealed how to develop efficient straightening methods with better, more economical dies.

Section size limitations on malleable iron are being extended as the result of an AFS-Training & Research Institute sponsored program. Two reports told about the addition of bismuth, tellurium, thallium, idium, and zinc to stop mottling in heavy sections and still maintain annealability.

The hardenability of pearlitic malleable has been increased by techniques disclosed at the Congress. New applications and more competitive serviceability will certainly result from the work.

16 – Safety, Hygiene and Air Pollution: *New concept for dust control on portable tools . . . air pollution control ordinances versus equipment.*

A new concept of high-velocity, low-volume dust control systems for portable grinders, chipping hammers, wire brushes, and swing grinders was demonstrated in a film produced by the British Ministry of Labor. Because these operations are mobile, they have always presented a challenge to dust control engineers. Every foundryman has this cleaning room problem. Here's a system which successfully copes with it.

U. S. Public Health Service Engineer D. G. Stephan presented an important review of typical dust collector designs, their limitations and the effect of air pollution control ordinances on the dust collectors currently being installed in the foundry industry. If you are contemplating an improvement in your dust control—and who isn't—this treatise should be used to guide your thinking.

"What is safety? Safety is forethought in action. It is looking ahead to see what can happen, and then taking the necessary steps to see that the wrong thing does not happen," advised G. A. Riley in his talk *Loss Prevention Through Accident Prevention in the Foundry*. An accident is a signal that something has been wrong in an operation. The lifeline of accident prevention is anticipation.

Now that you are aware of this vast panorama of technical progress, we urge you to read the complete texts of those technical papers which will influence your foundry future. Almost half of these Castings Congress papers have already been published in Modern Castings this year. The balance will be published in subsequent 1960 issues.

National Apprentice Winners

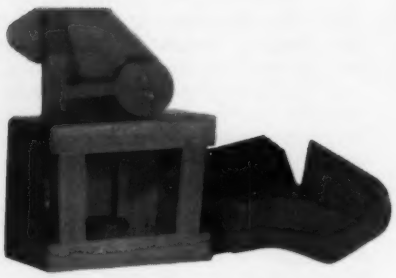
Apprentices from seven states and Canada won top honors in the AFS 1960 Robert E. Kennedy Memorial Apprentice Contest. Two of the winners had won national recognition in the 1958 National Contest.

Adam Kravetz, Progress Pattern Co., Detroit, first place winner in 1958, repeated again in 1960. James E. Gift, Jr., Dodge Steel Co., Philadelphia, won first place in the 1958 steel molding competition and this year took second place steel molding honors.

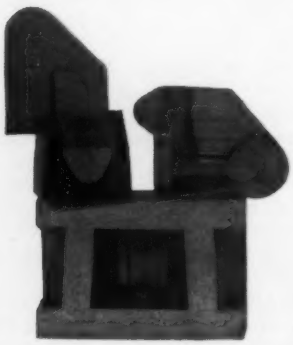
Eck Foundries, Inc., Manitowoc, Wis., was represented by two national winners in non-ferrous molding competition. Peter Durben took first place honors and Louis McKee was the second place winner.

Caterpillar Tractor Co., Peoria, Ill., had two national winners. Charles D. Lee won first place in metal patternmaking, and Rodney R. Kuykendall won second place in iron molding.

Wood Patternmaking



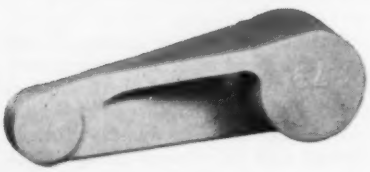
FIRST AWARD—Adam Kravetz, Progress Pattern Co., Detroit, Mich.



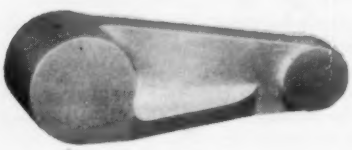
SECOND AWARD—Ron Koehnle, Reliable Pattern Works Co., Bedford Heights, Ohio.

THIRD AWARD—Duane Garn, Campbell Pattern Co., Santa Fe Springs, Calif.

Metal Patternmaking



FIRST AWARD—Charles D. Lee, Caterpillar Tractor Co., Peoria, Ill.

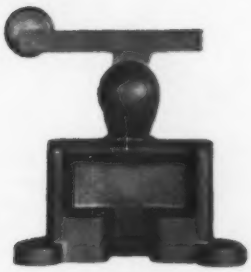


SECOND AWARD—R. J. Sekala, Ford Motor Co., Berea, Ohio.

THIRD AWARD—J. Puszykowski, Chevrolet-Saginaw Grey Iron Foundry Div., GMC., Saginaw, Mich.

Iron Molding

FIRST AWARD—Arvo Tynilainen, John T. Hepburn Co., Ltd., Toronto, Ont., Can.



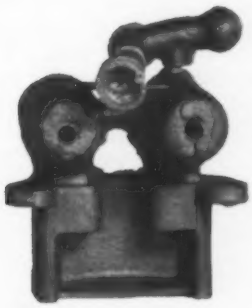
SECOND AWARD—Rodney R. Kuykendall, Caterpillar Tractor Co., Peoria, Ill.

THIRD AWARD—Malcolm Snyder, Atlas Foundry & Machine Co., Tacoma, Wash.

Steel Molding

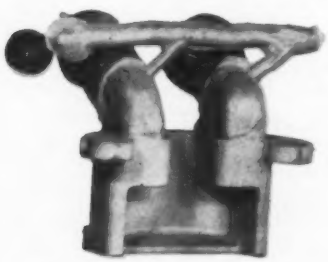
FIRST AWARD—James C. Leinss, Maynard Electric Steel Casting Co., Milwaukee.

SECOND AWARD—James E. Gift, Jr., Dodge Steel Co., Philadelphia.



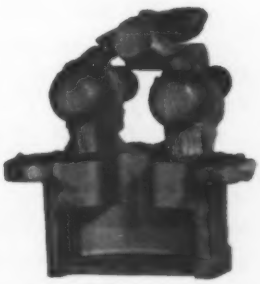
THIRD AWARD—Stephen Baich, Clark Equipment Co., Buchanan, Mich.

Non-Ferrous Molding

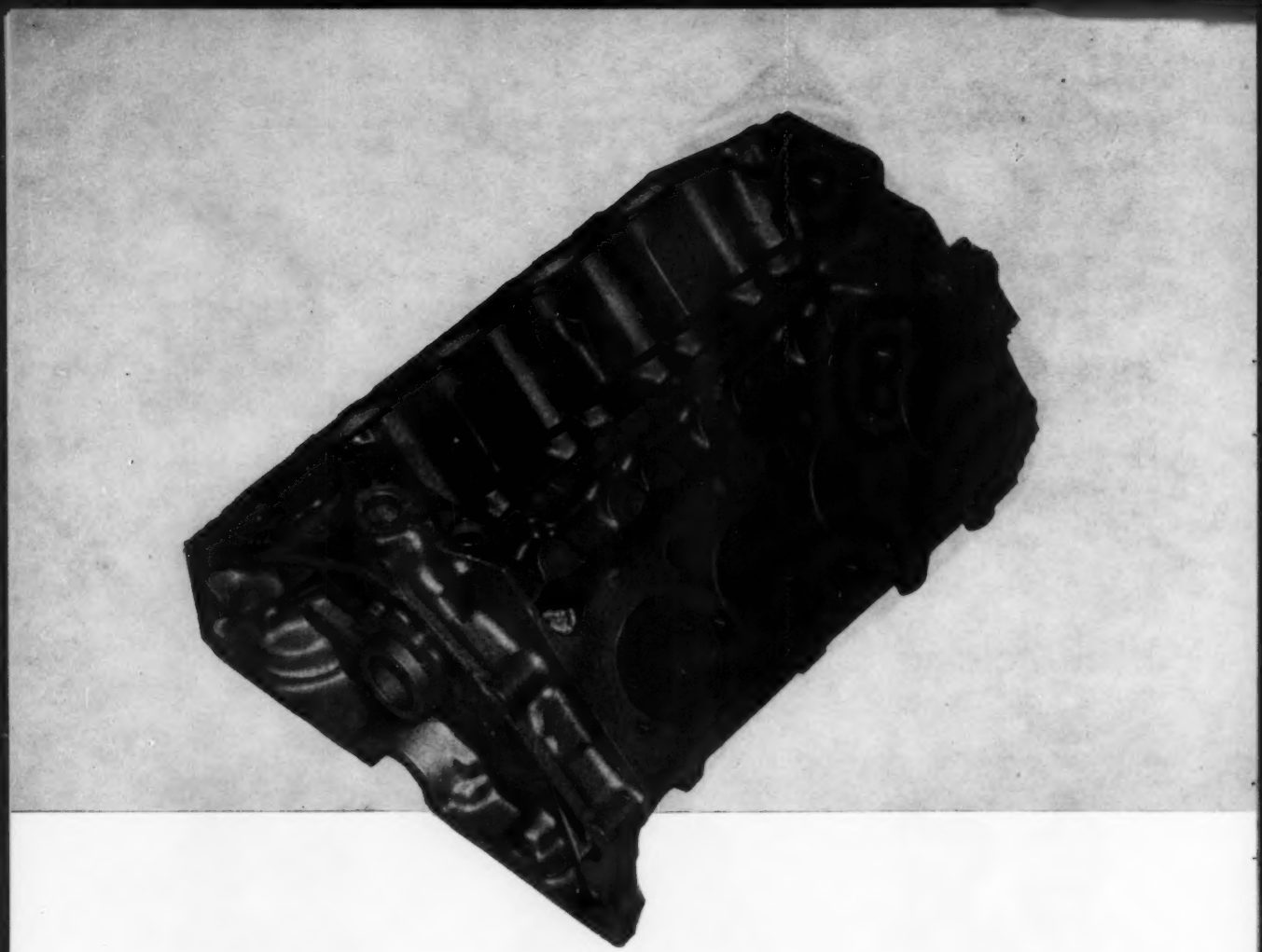


FIRST AWARD—Peter Durben, Eck Foundries, Inc., Manitowoc, Wis.

SECOND AWARD—Louis McKee, Eck Foundries, Inc., Manitowoc, Wis.



THIRD AWARD—Dennis M. Jenniges, Puget Sound Naval Shipyard, Bremerton, Wash.



Gray Iron vs. Aluminum

Has gray iron lost ground to aluminum in the highly competitive automotive casting market? C. A. Sanders has made a thorough study of this dynamic struggle in our industry. He presents here the gray iron side of the story. In championing the capabilities of gray iron as an engineering material, he tells why more than 12 million tons of gray iron castings were used in the last 12 months. One of the reasons is shown at the top of this page — a gray iron engine block made by the McKinnon Industries Ltd., Merriton, Ontario. Mr. Sanders is Vice-President, American Colloid Co., Skokie, Ill.

IN THE PAST YEAR much has been written on the advantages of cast aluminum over gray iron for use in the automobile engine. The time is long overdue for someone to come to the defense of gray iron and take up this challenge. The challenge is really not against the quality of aluminum, but rather to point out some of the differences between glowing fancy and sound engineering in its applications.

A considerable part of the success of the first economical foreign car that achieved great acceptance in this country was attributed to its lightweight aluminum engine. But how many of you know that over 100 pounds of this 198-pound so-called aluminum engine is gray iron and steel? The air-cooling shrouds, the cylinders, the crankshaft, the flywheel, the connecting rods, the camshaft and even such items as the generator are gray iron or steel and account for the largest portion of the engine. Then there's about 44-48 pounds of magnesium used for the engine block, transmission and other parts. So aluminum is only used for cylinder heads, pistons, timing gear and a few other parts.

Recent photos have shown that the combined weight of a pretty girl and an aluminum block was less than a gray iron block. Let's be realistic and add the gray iron insert sleeves, the water jacket covers and other cast parts to complete the assembly. Now the difference in weight between the two is not nearly so appreciable.

Initial statements inferred that no liners would be required in the aluminum engine of one of the first compact automobiles. This claim proved incorrect since cast liners did become an essential part of this engine.

Two New Engines

It is interesting to compare the engine designs of two well-known compact cars this year. One uses aluminum to save engine weight. The other uses gray iron instead of aluminum for the block. When these two engines are weighed with the crankshafts, camshafts, inserts and other accessories required for the motors to function, it is claimed there is only about a 7-pound difference in total weight. Furthermore, the car weight per horsepower of the aluminum engine is actually more than 4 pounds per car weight per horsepower over the one using gray iron. This is not meant to infer that one of these compact cars is better than the other. Let's just be aware of how well gray iron measures up to and even exceeds some of the claims made for aluminum.

The weight ratio of cast iron to aluminum is 2.6 to 1.0—that is, cast iron weighs 2.6 times as much as aluminum. When costs are considered, an equal volume of the two metals favors cast iron in either its liquid or solid form.

Weight of one small auto part may not be too important. Many high production lines actually add excess metal sections to eliminate certain labor and manual variables. Weight is slightly sacrificed in order to decrease scrap and repair. This is well known to production men but generally ignored by technical groups.

Here is another interesting example of how preliminary publicity on aluminum fell short of its claims—an automatic transmission. This two-part converter housing with case weighed approximately 78 pounds in gray iron. It was rumored that the job could be produced in aluminum for 19 pounds, thus making a more economical unit. So the conversion was made. It soon developed that to insure less leakage, more stability and rigidity, the casting had to be beefed up to approximately 26 pounds. During the interval, gray iron foundrymen redesigned the casting so it could be made under 60 pounds. So now the economies favored gray iron.

If the housing was made in gray iron, there would be a savings of approximately $2.50 per unit with machine-shop scrap under 2 per cent. It is understood that the housing unit cast in aluminum in permanent molds runs high in scrap and about 50 per cent require impregnation. But weight sales promotion is sometimes hard to overcome, particularly where top decisions have been committed and production foundries created.

Machining—Expansion—Corrosion—Others

Statements are often made that "aluminum costs less to machine and process." This is entirely incorrect. There is no proven data to support such statements under all conditions.

One of the seemingly forgotten engineering problems is the difficulty arising from joining unlike metals, such as aluminum and gray iron. There are thermal conductivity problems as well as differences in contraction and expansion to cope with. This is certainly true where manifolds meet cylinder blocks, if cast in different metals.

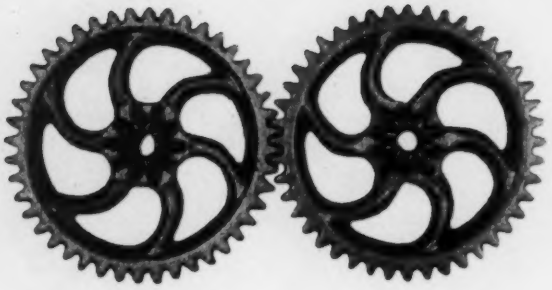
Superior corrosion resistance of aluminum automobile parts applies only when a great amount of engineering eliminates the possibility of galvanic couples

Why Not Aluminum?

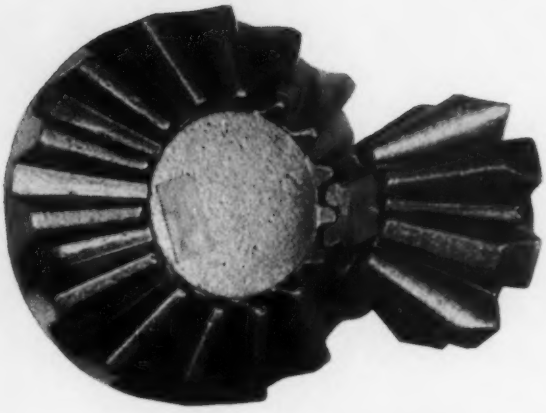
1) Gray iron has inherent machineability, corrosion resistance, thermal conductivity, dampening capacity, castability, and economy unmatched by aluminum.

2) Aluminum automotive engines still require many vital gray iron components.

3) Capital investment for mass production by permanent mold or die casting is staggering compared with gray iron-green sand facilities.



Hamilton Foundry, Inc., Hamilton, Ohio, specializes in green sand precision with gray iron castings.



Another example of cast-to-size gray iron parts designed for rugged duty application.

forming between dissimilar materials used in a cooling system. If the engine is liquid cooled, certain antifreeze solutions increase the hazard of corrosion and also create galvanic couples. Of course, smaller horsepower engines may be air-cooled; but as you increase horsepower, air cooling has not proven completely satisfactory.

Aluminum engines have the added cost of steel inserts for stud holes and other assembly requirements. It is understood that higher priced inserts are also required for certain exhaust valves in particular aluminum engines.

The possibilities of aluminum ever replacing gray iron in the present V-8 type engine block is quite problematical. There are relatively few die-casting machines in existence at this date that could do the large job required for the casting of a V-8 engine block. The larger the casting, the more the capital investment increases. It is believed that the inherent economy of sand cast gray iron will prove the victor in the battle.

Damping Capacity

Quite naturally, little has been said in aluminum publicity about its inferior damping capacity compared to gray iron. Gray iron has been popular for the automotive engines because of its ability to absorb noise and vibration. The chatter connected with aluminum air-cooled motors used for lawnmowers and motorboats is a marked contrast. Some automobiles are equipped with small, aluminum two-cylinder air-cooled compressors. The chatter and noise emanating from these small compressors is actually greater than that coming from the whole gray iron V-8 engine block. Chattering must be accepted when lightweight metals are used.

The current trend seems to be toward the use of higher silicon-aluminum alloys in die and permanent mold casting. However, as the fluidity is increased by use of silicon and other alloys, microshrinkage tends to occur. In most cases, the thinner the cast aluminum walls the greater the susceptibility to micro shrinkage. So it's often necessary to impregnate die castings to seal microshrinkage that develops in thinner walls.

The only other alternative is to "beef-up" the section thickness so microshrinkage decreases. This solution offsets the argument of the weight factor and costs begin to favor gray iron.

European foundrymen point out that thin-wall aluminum castings are susceptible to warpage, bending and loss of rigidity. In contrast, gray iron motor blocks display considerable superiority in these three properties.

Heat Treatment Required for Aluminum

A serious drawback to the future of cast aluminum cylinder blocks is the expensive heat treatment required. The heat treatment equipment necessary to process 10,000 units per day would cover an area estimated to be greater than two acres!

Die Castings—Permanent Molds

Several European foundries presently cast not only by sand but by pressure injected die cast and gravity fed permanent molds. They state that if permanent mold castings are scheduled at the same rate as sand castings, the initial investment for equipment may be prohibitive.

Permanent molds are often quite complex. They may use many liners, or inserts, which are difficult to maintain. Molds must be cleaned regularly, sometimes in a strong caustic solution. Molds, or inserts, require frequent cleaning by heavy wire brushing. Mold washing and coating with a refractory is also expensive. Proper temperatures in coating must be

Gray iron and green sand work together at Lodge Mfg. Co., South Pittsburgh, Tenn.

Note the smooth surface and accurate teeth on this gray iron casting ready for use without machining.

considered in order to prevent sticking of the cast parts in the permanent molds. With the larger automotive castings this problem is still a puzzle. Research and development may have cured the problems but production has not.

Even when castings are ejected properly from permanent molds, after ten to fifteen casts their surface appearance is often inferior to a good sand casting.

When casting into dies or permanent molds, the molds are tied up for minutes during metal solidification. For example, a normal gear box may require over six minutes to solidify in a gravity fed permanent mold. This loss of production is expensive. If extra molds are required to increase production, costs soar.

"Aluminum gravity-cast permanent molds work better than pressure die-cast molds for gear boxes, housings and certain other parts" so state several European people. Nevertheless, gravity-fed permanent mold castings are heavily risered. Riser removal by sawing or cutting is expensive. Gray iron risers can be quickly removed with a sharp hammer blow.

Sand Casting

Companies too often overlook the possibility of casting metals in sand molds where large size and good casting finish are needed. Sand molds can do the job equally as well as the average of 100 casts from a permanent mold. The larger the casting, the more sand is favored. One large automotive experimental foundry proved that the following sand mixture produces either gray iron or aluminum castings as dimensionally accurate as the average of 100 permanent molded automobile castings. The mixture contains:

By Weight
92%—Silica or bank sand, 100 AFS gfn or finer
3%—Western bentonite
2%—Southern bentonite
3%—Cellulose carbon
2.7%-3%—Temper water

Some foundries desiring extremely fine finishes have found that naturally bonded sand with no more than 12 per cent AFS clay content can be added to the above mixture and improve casting finish. Adding from 5 per cent to no more than 15 per cent of these naturally bonded sands improves molding characteristics.

Cellulose carbons, a special mixture of a volatile carbon, a graphitic carbon and a fixed carbon are rapidly becoming a popular sand additive.

Mulling of the sand mixture is important—at least five minutes for slower mullers and not less than 90 seconds with the rapid or faster mullers.

Some foundries have cast one gray iron casting then an aluminum casting, alternating gray iron and aluminum in the same sand mixtures, with casting results equal to that obtained in the larger automotive permanent molds.

Present automotive foundries which are geared to high production can use the above sand mixture with equal results and less cost than claimed for the permanent mold processes.

If the shape is not too complex, sand is the natural casting medium. Should the casting have deep and narrow draws, such as fins, or other complicated parts, give the job to the die or permanent mold people where such castings rightly belong.

But gray iron is not licked. Records prove that it is the least expensive metal to cast, yet furnishes the most over-all favorable properties for the driver at the wheel. There is a feeling in the gray iron industry that had the industry devoted more effort towards publicity, education and product improvements, the position of aluminum would not be as strong as it is to date.

EXCLUSIVE

World-wide Roundup . . .

Capsule comments on what's new in metalcastings as viewed by experts from many nations

Germany

J. Gunther Schwietzke, Dr.- Ing. habil–Fabrikant . . . J. G. Schwietzke Metallwerke, Dusseldorf, Germany. (Dr. Schwietzke was 1958 President of the Committee of Foundry Technical Associations) . . . "West Germany is enjoying an industrial prosperity unmatched in its history. As a result, the average working man can now at last afford to own an automobile. High taxes and expensive gasoline strongly influence car buying habits.

"This domestic automobile industry is our biggest consumer of aluminum castings in Germany. Sand, permanent mold and die casting processes are all used. Because of poor wear resistance of even the 24 per cent silicon alloy, cast iron liners are used in aluminum engine blocks." ■

Australia

H. A. Stephens, . . . Sr. Research Officer, Commonwealth Scientific & Industrial Research Organization, Melbourne, Australia . . . "The Australian metalcasting industry comprises some 1000 foundries employing about 22,000 and producing 350,000 tons of castings per annum. In the automotive field, General Motors Holden Ltd. produces the Holden–a six-cylinder, medium-sized car designed for Australian conditions.

"Zircon is used as a mold dressing and for cores. A considerable tonnage is exported to American foundries. Ilmenite has recently attracted attention as a base for synthetic brass sand. Its high refractoriness suggests the possibility of ilmenite being an inexpensive substitute for zircon." ■

CAST METALS have no nationality so consequently they perform with the same idiosyncrasies in the United States, Russia, France, Germany, etc. Foundry technology has no language. Only in the communication of this knowledge does language present a barrier.

MODERN CASTINGS has broken through this particular barrier by bringing to you this world-wide roundup of metalcasting technology, written in English. Much of this was obtained through personal interviews with overseas foundrymen attending the AFS Castings Congress and Exposition.

France

Here are a few of the interesting comments made by Robert Ronceray, President of S. A. Bonvillani & Ronceray, Choisy-le-Roi, France . . . "American foundry equipment is popular in Europe but it is built over-seas under licensing agreements with U. S. companies. American firms can afford to spend more money on equipment development because they have a bigger sales market in which to amortize their original investment.

"Sand preparation, handling and molding machines have to be modified to suit peculiarities of French sand. Our sand contains twice as much bond as normally found in America. High bond permits use of flasks without bars. Such flasks are helpful to jobbing foundries where short runs on a variety of pattern shapes are possible with the same flask size.

"You may be surprised to learn that diaphragm molding was invented by a Frenchman named Devielle in 1898; and that air-set cores have been used in France for the past 15 years!"

Robert Ronceray enthusiastically talks about the French foundry industry while attending the AFS Castings Congress and Exposition.

Russia

Highpoint of international revelations came at the Sand Division Dinner where Prof. Ylian A. Nekhendzi, Head of Foundry Production Chair, Leningrad Polytechnic Institute, was scheduled to present a paper entitled *Foundry Production in the U.S.S.R.* At the last minute it was learned that Dr. Nekhendzi would be unable to make his trip to this country.

Fortunately his paper had been sent over in advance so it was possible to read it at the Sand Dinner. Here are some excerpts.

"Vigorous development of foundry production commenced only with the industrialization of the U. S. S. R. *Pressure Solidification*: Wide industrial application has resulted from a process developed for producing intricate and large aluminum alloy castings by solidification under pressure. In this process, castings in filled molds solidify in special chambers which are under pressure sufficient to depress evolution of gases in solidifying metal and improve the feeding of castings from risers.

A dense casting is obtained, without gas and shrinkage porosity and with higher strength and plasticity. *Casting Cooling*: The Novo-Kramatorsk Engineering Plant has developed a method of forced cooling of large castings which reduces the period of cooling in a mold by half, thus considerably improving the production indices.

Forced cooling is accomplished by blowing compressed air with water through large pipes. The pipes are placed 6 to 8 in. from the pattern,

Continued on page 42, column 3

Belgium

Prof. Albert De Sy . . . University of Ghent, Ghent, Belgium. . . "Great progress is being made in Europe with processes for directly reducing iron ore to molten metal suited for alloying and pouring into castings. Pilot furnaces have operated as low as two tons of molten iron per hour. With production costs down, direct reduction is cheaper than cupola melting.

"The use of pig iron in foundries is also being curtailed by the rapidly expanding use of induction furnace receivers coupled with hot blast cupolas using all-scrap charges. About 100 induction furnaces have been installed in Europe in the past year for receiving molten iron from cupolas. Composition and temperature is adjusted here before transfer." ■

Japan

Yoichi Tamazaki . . . Tokyo Metropolitian Industrial Research Institute, Tokyo, Japan . . . "The Japanese foundry industry is now most interested in improving its productivity. Many individuals as well as teams of foundrymen have come over to the United States to study production techniques. Our Japanese government is lending assistance in this productivity program. It has been found that labor comprises 55 per cent of the total cost of a casting here in your country compared with only 30 per cent in Japan. In spite of low labor costs our efforts are being directed toward savings through increased mechanization. "Japan is now developing an extensive system of castings specifications." ■

Italy

Fritz Hansberg . . . President of Hansberg Shooters, Inc., Modena, Italy . . . "The CO_2 process is being used far more extensively in Europe than in the United States. For instance Mercedes Benze cylinder heads and water jackets are aluminum cast into CO_2 molds with CO_2 cores. Cores are washed out of castings with water.

"CO_2 cores weighing many tons are common in steel castings. One practice is to make the outer shell of the core in sodium silicate bonded sand; fill with heap or dry sand and seal with green." ■

India

Sampat Kumar G. Somani . . . Director, Sree Engineering Products, Ltd., Calcutta, India . . . "With the help of our Indian government we are expanding our industrial capabilities. We have now reached the point where all our cars are built in India.

"Foundry capacity is growing and is meeting India's needs with the exception of malleable iron castings, some of which are still being imported from England.

"Most of our foundry equipment is from England and Germany. But we are now looking at your country." ■

England

R. G. Godding, . . . British Cast Iron Research Association, Alvechurch, Birmingham, England . . . "A new process which is competitive to the shell process is now receiving considerable attention in England. This is the hot core box method of making cores. Sugar is used as the sand binder and ammonium sulphite as a polymerizer. Mix is rammed or blown into hot core box at 250 C where it cures in about one and a half minutes. The inexpensive binder and rapid curing make this process attractive for small core production." ■

Switzerland

Ernst Wickli . . . Sales Manager, George Fisher, Ltd., Schaffhausen, Switzerland . . . "There is a marked difference between foundry equipment built in the United States and that built in European countries. American engineers build machines as strong as possible while Europeans build only as strong as necessary for the machine's function.

"One reason for buliding lightweight equipment in Europe may be attributed to the high cost of raw materials going into construction of the machinery." ■

Continued from page 41

parallel to each other, and connected into sections, each having its own blast inlet and outlet. Blowing begins before pouring; several hours later water is supplied by spray or jet.

Such evaporation cooling is very effective as it may absorb as much as 35 per cent of the heat content of the casting. It is also successfully employed for cooling separate sections of large castings, increasing the effect of external chills and eliminating the danger of hot tears.

Pressure Risers: The efficiency of risers increases if they operate under pressure provided by special gas charges or gas-generating cores.

To provide pressure in blind risers for large castings, compressed air at 4-5 atm from the shop air-duct system is sometimes supplied to them.

Pressed Molds: Mention should also be made of a new method of casting in molds pressed under pressures up to 285 lb per sq in. instead of the usual 40 to 70 lb per sq in., using flowable, fine-grain molding mixtures containing pitch, bitumen, etc. The simultaneous effect of high pressure and vibration results in uniform packing and good surface quality.

Steel Cast in Permanent Molds: Steel castings weighing over 5 tons are obtained in steel molds. Such molds, weighing over 10 tons and having a wall thickness of 5.9 to 6.7 in., have better resistance to erosion, tears and warping than iron molds. Special investigations have shown that the content of carbon and sulphur in the steel for molds should not exceed 0.1 and 0.025 per cent, respectively.

Cast Iron Sheets: A modification of casting in water-cooled metal molds is a process developed for obtaining flexible sheets from iron in rotating water-cooled metal molds (rolls).

With continuous operation of the ordinary plant, a strip 0.06 in. thick and 40 in. wide is produced. Sheets may be obtained 0.03 to 0.9 in. thick and up to 46 in. wide.

Liquid Metal Stamping: The method developed for casting with "piston-pressure" crystallization and its modification of "Liquid Metal Stamping" have found wide application for nonferrous alloys. Poured into an open mold, the metal during solidification is subjected to pressure in a hydraulic or pneumatic press. The castings obtained are dense, they are without risers, and have central holes as well as appendices if cores have been placed in the die molds.

There is a basic similarity in the problems facing the Russian and American foundryman. However, solutions often display marked difference.

"Have Courage to Try the New--and Fail!"

WILLIAM J. GREDE thus dared foundrymen in his Charles Edgar Hoyt Memorial Lecture at the AFS Castings Congress. Mr. Grede, now serving as president of J. I. Case Co. as well as chairman of the board, Grede Foundries, Inc., spoke with the vision inherent to a man who has molded a brilliant career in the foundry industry.

The speaker warned that our age has become so determined to achieve security that it is suffering from a "failure of nerve." Grede continued, "The type of research necessary for the solution of metalcasting problems cannot flourish in an atmosphere which emphasizes security . . . We must urge our technical and research groups to have a dynamic approach to problems and to have the *courage to fail*. They must also have the dogged determination never to stop searching for a solution no matter how often they may fail in the attempt."

The speaker did not look for any substantial competition from overseas metalcastings imports. However there would be an indirect impact on the casting market resulting from imports of finished products containing cast components.

Commenting on government taxation, Grede said, "Those who produce most and create the largest income are penalized the most. Unlike American business that rewards the productive, our Government taxes the productive. The progressive income tax has done more to socialize our economy than any other single act of Congress."

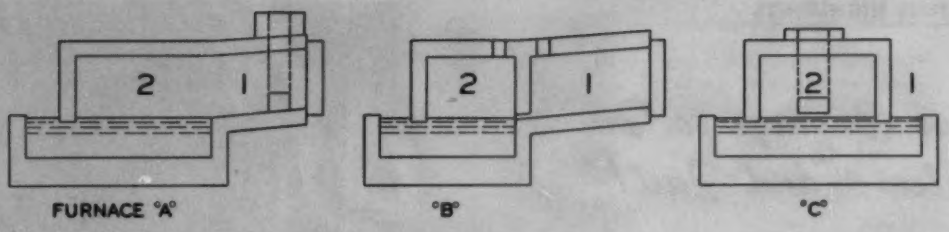
The complete text of Mr. Grede's important lecture may be found on page 59.

"Government taxes penalize the productive. Those that produce the most are also taxed the most."

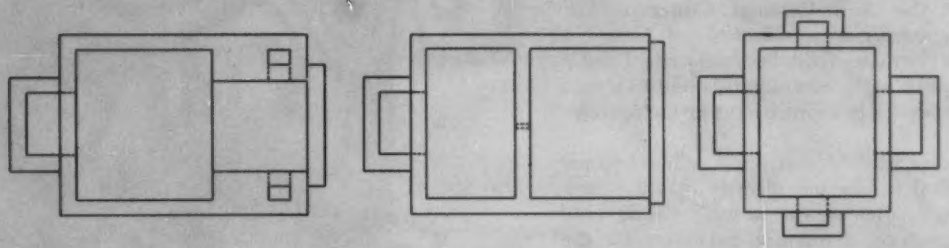
"We must urge our technical and research groups to have dogged determination and the courage to fail."

"I do not look for any substantial casting competition from overseas . . . except for the impact of finished product imports on our casting market."

"Our industry has spent most of its effort in the past making good castings and less toward telling customers about metalcasting developments."



SCHEMATIC ILLUSTRATION OF ALUMINUM MELTING FURNACES



Aluminum Melting Practices for Permanent Mold and Die Casting

by Walter Bonsack, Chief Metallurgist, Aluminum & Magnesium, Inc., Sandusky, Ohio

THE DOLLAR SIGN is a more serious foundry factor than any metallurgical and technical factor when it comes to making salable castings. Most foundrymen know how to make good castings; but two important ingredients, price and competition, hold them down to a level which is unpleasant but necessary.

Most foundrymen today purchase their alloys custom-made to specification at a price equal to the requirements demanded from them. They are similar to frozen meals. All that needs to be done is to heat the alloys to the prescribed temperature and pour them into the mold or die.

Both permanent mold and die-casting processes demand a steady supply of metal under constant conditions. Therefore, batch melting equipment such as pot furnaces should not be used. The trouble with a pot furnace is that you constantly add fresh, slightly preheated ingot and/or scrap material during the pouring operation. This practice causes considerable undesirable variation in pouring temperatures; introduces undesirable nonmetallic elements; and leads to fall out of aluminum-iron-manganese compounds from the melt. These three factors cause higher scrap, lower properties and poor machinability.

Pot furnaces should be supplied constantly with well prepared hot metal from a central melting station and be skimmed before use. With two pot furnaces per installation, one can act as a metal supply to the mold while the other serves to melt, flux, grain refine, degas and generally prepare the metal for use. Alternating use of a two-pot setup will prove quite successful.

About 25 years ago small refractory furnaces were introduced for permanent mold and die casting. These are small smelting furnaces with a dipping well on the outside. Some have a charging well on the opposite side. Lately a newer version has been developed —the so-called dry-hearth furnace. These three types are schematically shown in the schematic illustration above.

Furnace A

In furnace A, the cold charge is preheated by the flue gases in the preheat chamber (1) and at proper intervals transferred into the molten metal. Usually a thermo control in or near the dipping well regulates the heat supply. This way of charging brings oxides into the main body of the melt so frequent skimming is necessary to get good heat transfer from the heating chamber to the melt. Treating the metal with grain refiners, etc., is cumbersome because you have to work against an open heating chamber.

Furnace B

Furnace B is the latecomer in the line of reverberatory furnaces and primarily popular for its "fast" melting. Metallurgically speaking, it is a smelt furnace (combustion chamber) with a drip pan attached. This furnace consists of two chambers, each heated

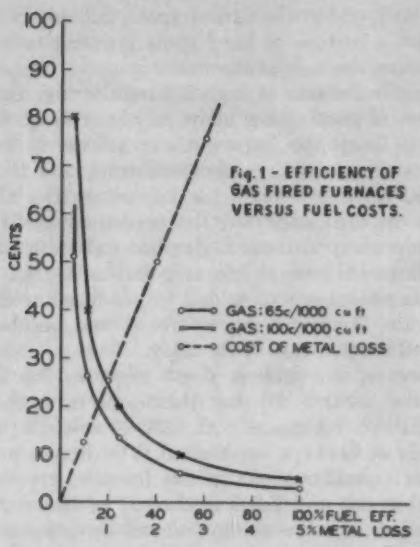


Fig. 1 - EFFICIENCY OF GAS FIRED FURNACES VERSUS FUEL COSTS.

QUALITY + ECONOMY

Pre-alloyed ingot is like a frozen meal . . . just heat it up and serve to the mold. The only difficulty is that there is many a slip betwixt and between. Metallurgist Walter Bonsack tells you in this article just what controls must be exercised to produce quality casting at a competitive price. High on the list is selection of proper furnace with proper temperature-control devices.

A common source of difficulty lies in pouring permanent mold castings too hot and die castings too cold. In one case critical elements burn out and in the other they sludge out. As metal temperatures rise so does hydrogen absorption. A sample test for gas content and proper degassing procedures are covered. And there is nothing quite so fatal to casting quality as a small dose of magnesium containing scrap in an aluminum-silicon alloy melt and vice versa.

individually. Metal in ingot or scrap form is charged into chamber (1). The burner flame impinges directly on the charge with full ferocity. The metal melts fast and drips through the flame, oxidizing rapidly. Melted metal collects on the hearth and reluctantly flows into the drip pan chamber (2). Often a hole has to be poked through the oxides so the metal will run into the forehearth. There it will be adjusted up or down to pouring temperature and flow out to the dipping well to be ladled into the molds.

For good, conscientiously prepared, ready-to-melt-and-pour aluminum alloys, this is Dante's Inferno. Scrap loss due to gas and bad machining often reaches 20 per cent.

This technique is fast, gets the most heat out of fuel by oxidizing the aluminum. Thus aluminum is being melted by using itself as a fuel. One pound of aluminum burned (oxidized) produces about 12,000 Btu's. The melting efficiency of this type of furnace is reported to be high. It certainly should be. The heat supplied by oxidizing aluminum is so high that it is used for thermit welding, for incendiary bombs and other such pyrotechnic processes. Figure 1 shows the efficiency of gas-fired reverberatory furnaces and the fuel cost at various efficiencies. Also plotted is the loss of money due to the oxidation of the alloys. It is evident that gas is a cheaper fuel than aluminum. As fuel efficiency improves, oxidation losses increase. These losses are greater than the gain in fuel efficiency. This figure does not take into account the losses due to scrap castings and customer good will.

Melting this way only 95 per cent of the available aluminum is recovered and this has poor quality. When smelters use this type furnace they remelt, rework and refine the ingot metal before offering it for sale. Can the foundry afford to put this highly oxidized metal with low properties into castings? Castings so produced may meet minimum specifications but this is no credit to foundries. Specifications are too low to give good foundries credit for ability.

Other factors enter the picture. For instance, an aluminum-silicon alloy needs sodium modification in permanent mold castings to produce maximum ductility. Sodium oxidizes more easily than aluminum yet it needs to be present to produce the right properties. So excessive heating burns out the sodium and returns the alloy to an inferior condition. Magnesium has definite functions in heat-treatable aluminum alloys. It, too, oxidizes in preference to aluminum. Beryllium, titanium and aluminum are also oxidized. Many of the elements added judiciously in the preparation of alloys are lost to gain some price advantages to meet competition.

Furnace C

Furnace C is one of the best furnaces for high-melt quality. It works on a principle similar to Furnace A except the metal is charged cold into a charging well, usually opposite the dipping well. The waste or flue heat may or may not be utilized to preheat the charge. If the furnace capacity is sufficiently large and the burner arrangement appropriate, then metal on the discharge or dipping side will be of uniform temperature and quality.

This type furnace presupposes mass production on one type of alloy because changes from one alloy to another would be expensive. Conditions are ideal because the alloy is melted in a bath of aluminum at low temperatures. Oxidation is at a minimum because the solid metal is fed into liquid metal and melted by the body heat of the liquid metal with the exclusion of air and combustion products. This gives the maximum return for the metal charged.

By charging the metal in an outside accessible charging well, skim need not travel into the heating chamber to deter heat absorption by the main metal

bath. Consequently, skimming of the main metal bath is less frequent and is done outside the furnace proper. Grain refining or other treatments can be made comfortably without opening a hot furnace door and facing a hot furnace chamber. By arranging burners and controls in the proper manner, metal can be fed constantly into one end of the furnace, processed and delivered for pouring at the other end at proper temperatures and consistency.

Temperature Control

Permanent Mold Casting—Seldom is too low a temperature used in permanent mold castings since cold shuts and imperfect filling of the mold rapidly indicate this condition. Too high a temperature is more apt to be the case and is not easily recognized. Figure 2 shows a casting which had shrinkage difficulties due to high pouring temperature. Temperatures of 1600-1650 F were unknowingly used when 1250 or 1300 F would have been ample to produce this casting. Crystals 1.5-in. long developed. High temperatures cause large grain. With the large macro grain goes a large micro grain. All constituents are large and tend to decrease properties otherwise available.

This particular alloy, shown in Fig. 3, is a 356 (SM 70) alloy. Besides silicon it normally contains magnesium for strength and sodium for ductility. This micrograph reveals the silicon in large needle form, indicating that all sodium has been burned out and ductility as well as machinability lost. Analysis showed magnesium also lowered. The only thing gained was an undesirable high gas content. Backing off pouring temperatures to 1350 F eliminated all difficulties.

Die Casting—On the other side of the pouring temperature scale is the die caster. He is not too much worried about filling the dies. He usually has plenty of power to push metal into the thinnest sections. Low pouring temperatures allow more castings (shots) per man-hour or machine-hour. So the tendency is to go to the other extreme—too low a pouring temperature.

It is not uncommon to see pouring temperatures below the liquidus temperature of the alloy used. This practice leads to sludge accumulation in the furnace and hard spots in the castings. Every pound of sludge taken out and discarded is a monetary loss. Besides, you are throwing away those very alloying elements you insisted on having added to the alloy in the first place. The "cheapest" pouring temperature is the lowest which will *not* produce sludge. Then there will seldom be "hard spot" difficulties. Figure 4 shows a culture of hard spots growing in an alloy which was die cast at too low a pouring temperature.

The introduction of high silicon alloys presents the problem of pouring the alloys at high enough temperature to keep the hypereutectic silicon in solution. By choosing too low a temperature (1250 F instead of 1450 F) one defeats the advantage the alloy offers to the die caster over the permanent-mold caster. It is important in these high silicon alloys to produce the primary silicon as fine as possible. A grain refiner such as phosphorus is added to produce the fine silicon grain. Pouring temperatures should be above the liquidus temperature of the alloy.

However, die casters don't seem to be inclined to cast at 1400 F. Instead they pour no higher than 1250 F. What happens? At 1250 F only 15 per cent silicon can be kept in solution. The excess over this amount crystallizes out in the furnace, grows to respectable size and floats to the top of the melt to be poured off like the sludge caused by iron and manganese. Figure 5 illustrates the large primary silicon floating in the melt and the same, but much smaller crystals, produced by the fast chill of the die. With a little higher pouring temperature this silicon could be held in solution and produce better machining and superior castings.

Thus melting and pouring temperatures are of prime importance to the quality of the casting. Reliable automatic temperature-controlling instruments are therefore a must.

Gas Absorption

Of the gases which can be dissolved in aluminum, hydrogen is the worst offender. The higher the melting and pouring temperatures the greater is the solubility of hydrogen. The lower the temperatures involved, the lower will be the gas absorption.

Normally hydrogen enters the metal from the combustion products and moisture adhering to the charge. Often, though, it is willfully produced by "treating" the metal with green wood, potatoes or "boiling" flux. To add "boiling" flux or the other hydrogen producers is absolutely wrong. Unfortunately, dissolved hydrogen precipitates in the casting in the form of objectionable porosity.

The die caster seldom has to worry about the gas content of the molten alloy because of the above-mentioned tendency to keep the melt on the low side of the temperature scale. What little gas is dissolved

Fig. 2 . . . 3/8 X

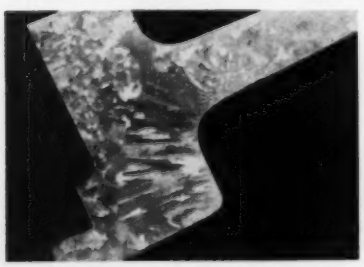


Fig. 3 . . . 100 X

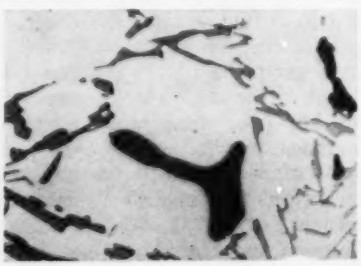
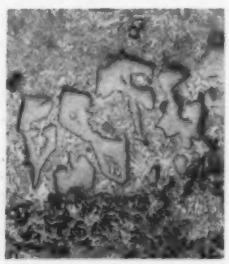


Fig. 4 . . . 12.5 X



has no chance to precipitate due to the rapid solidification in the die.

Solid, pore-free permanent-mold castings require thorough degassing of the liquid metal. Dry gases like chlorine or nitrogen when gently bubbled through the melt will degas the metal rapidly. Degassing fluxes are recommended where these gases are not available or not permitted by city ordinances. These fluxes either in pill or powder form usually contain hexachlorethane, a compound containing about 90 per cent chlorine and 10 per cent carbon. Heat decomposes them into chlorine gas and carbon. The chlorine then becomes the active degasser.

Testing the melt for gas content is done effectively by letting a sample slowly solidify under vacuum. A flat or concave surface of the regulus obtained usually indicates relative freedom of gas. Cutting the sample vertically will further prove freedom of gas if no voids are exposed in the cross section. A convex surface indicates the presence of gas in the melt. This test is simple, reliable, fast and relatively inexpensive.

Grain Refinement

Elements like titanium, boron, zirconium, beryllium, sodium and phosphorus are usually added in the preparation of alloys by smelters. Some of these may get lost in the foundry or their effectiveness diminished by mishandling when remelting foundry scrap. To produce uniform quality of castings, these elements should be replenished frequently in the foundry. To illustrate the lack of grain refiner and the effect on the casting quality, Fig. 6 and 7 are shown.

Figure 6 depicts the macrograin of a head section of a diesel engine piston. This section cracked in service. Figure 7 shows a micrograph of a passenger car piston skirt which also cracked in service. Both failures were due to large macrograin. The term "large is a relative one; it is directly related to the cross-sectional area of the casting. The head section is an inch or more thick; some crystals are as large as a dime with only two to four per cross section. In the skirt sections the crystals are much smaller; but in relation to the cross section they are large, i.e., one to three crystals thick. Both these structures, heavy or thin, are structurally weak as evidenced by their failure.

An adequate content of grain refining elements would have provided a much larger number of small crystals with more resistance to cracking. Grain-size control with grain refiners is a must in permanent-mold castings because the heavy unidirectional chill caused by metal molds encourages dendritic crystallization.

Silicon Modification

Sodium is a modifier of silicon in aluminum alloys containing up to 13 per cent silicon. Above 13 per cent silicon the size and shape of the silicon can be controlled by phosphorus. Silicon crystallizes in needle or plate form, and, given the chance, will grow until it impares ductility. Sodium will disperse silicon into fine globules and make the alloys more ductile. Sodium is quite elusive and is easily lost in melting. The only certain way to have sufficient sodium present at all times is to add it periodically to the furnace before pouring the castings.

Scrap Management

Most foundries re-use their foundry scrap in amounts up to 50 per cent or more of the furnace charge. Since many foundries use more than one alloy, scrap must be carefully handled and segregated. The accidental addition of high-magnesium-alloy scrap to a ductile aluminum silicon alloy will ruin it. Conversely, even the smallest contamination of high-magnesium-aluminum alloys with silicon alloys will make them useless. For instance, a 10 per cent magnesium-alloy melt tested, after heat treatment, 28,000 psi tensile strength and three per cent elongation. Instead of a white, silky fracture, it appeared like cast iron. Someone had used some 356 alloy scrap to cool the melt down to pouring temperature. Only 0.5 per cent silicon was mistakenly added. But all castings had to be scrapped and the metal could not be used in any way. Starting with fresh metal and working carefully, they brought the next castings up to 52,000 psi and 25 per cent elongation.

Furnace Room Personnel

The process of preparing metal is complicated, must be supervised with knowledge and carried out with respect and care. It is the hardest job in the foundry because it is hot, uncomfortable and, if not fully understood, dangerous. But it is the most important job in any foundry. It is hardly believable that large, modern foundries employ all the modern equipment and competent supervision just to throw money away. They know that the only way to produce good castings economically is by using every advantage the science of aluminum metallurgy offers.

Fig. 5 . . . 50 X

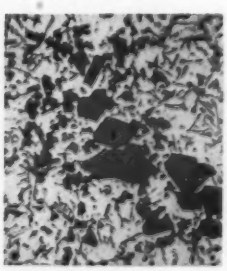


Fig. 6 . . . 3/8 X

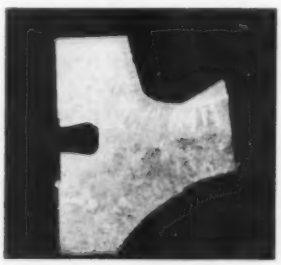
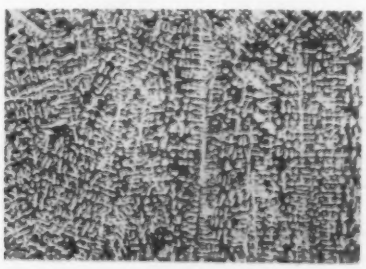


Fig. 7 . . . 25 X



Molding . . .

This is the third of a series of four articles presenting the official 1959 exchange paper from the American Foundrymen's Society to the Australian branch of the Institute of British Foundrymen. The authors are R. W. Heine, University of Wisconsin, Madison, Wis.; E. H. King, Hill & Griffith Co., Cincinnati; and J. S. Schumacher, also of Hill & Griffith. The series, first appearing in the April 1960 issue, will be concluded next month.

THE PREVIOUS discussion dealt with the principles of proportioning ingredients in synthetic molding sands. While the ultimate properties are fixed by the sand ingredients, the properties displayed in a mold are largely determined by the molding operations. Molding compacts the sand. Compaction, measured as increased bulk density, increases mold hardness, green compressive, shear and tensile strengths, and dry and hot strengths.

Table 1 provides bulk density ranges existing in sands from minimum to maximum. The bulk density attained when molding stops largely determines the properties which the molded sand aggregate displays.

TABLE 1—BULK DENSITIES OF SOME TYPICAL MOLDING SANDS

Material	Bulk Density lb/cu ft	(%) solids*	(%) voids**
1) Silica sand (clay free)	100-115	60.4-69.5	39.6-30.5
2) Dry sands plus southern or western bentonite and carbonaceous additives having 9-11% AFS clay, 4-8% total combustible, 60-75 AFS fineness	90-105	54.4-63.5	45.6-36.5
3) Molding sand in No. 2 tempered with water to molding consistency			
a. Riddled	50- 65	30.2-39.2	69.8-60.8
b. Compacted to 70-85 mold hardness	65- 85	39.2-51.3	60.8-48.7
c. Compacted to 90-95 mold hardness	90-105	54.4-63.5	45.6-36.5
4) Fire-clay bonded molding sand; 12-15% AFS clay, 4-8% total combustible, 60-75 fineness, tempered with water			
a. Riddled	60- 75	36.2-45.2	63.8-54.7
b. Compacted to 60-85 mold hardness	75- 95	45.3-57.3	54.7-42.7
c. Compacted to 90-95 mold hardness	105-115	63.5-69.5	36.5-30.5

* True density of solid silica = 165.4 lb/ cu ft

$$\text{Per cent solids} = \frac{\text{Bulk Density}}{\text{True Density}} \times 100;$$

$$\text{Example: } \frac{100}{165.4} \times 100 = 60.4$$

** % Voids = 100% − % Solids

Ability to express the properties of sand over a range of bulk densities and molding or ramming effort is important. Also the properties measured with laboratory specimens need to be related to properties in the mold.

Mold Hardness

The mold hardness test, (see reference 1) provides a convenient measurement for relating properties in the AFS 2.0x2.0-in. diameter specimen to properties in the mold (reference 4). Fortunately, the mold hardness test indirectly measures the bulk density of a particular sand. In addition, all green properties are related to mold hardness in a way similar to that of bulk density. If the mold hardness starts at about 60 and increases to 95 then the bulk density of the sand is increasing from the lower to the higher values in Table 1. Strength properties are also increasing.

Comparison between laboratory specimens and mold requires that specimens be prepared over a wide hardness range. So any mold hardness measured in a mold can be compared with equivalent hardness in a specimen. Figure 1 shows the relationship between mold hardness and green compressive strength over the hardness range of 60 to 95 for new sand mixtures containing 3, 6, 8 and 12 per cent western bentonite. The graph shows a progressive increase of green compressive strength with mold hardness.

The graph also demonstrates the dependence of green compressive strength at a given mold hardness on clay content in unsaturated sands. In clay saturated sands, green compressive strength reaches a maximum value at any given mold hardness and will not increase further by increasing clay content. The upper curve in Fig. 1 therefore represents the maximum MH-GCS relationship for all clay-saturated sands, regardless of clay type (reference 4). Further, this relationship is not affected by moisture within the normal percentages of molding sands.

Producing these curves requires special specimen ramming equipment. The standard AFS rammer drops

a 14-lb weight 2 in. when ramming the specimen. To obtain specimens of low hardness, 60 to 80 MH, a 2.0-lb weight is substituted for the 14-lb weight. Specimens covering the hardness range are then produced by varying the weight of sand in different specimens and the number of rams with the 2.0 or 14.0-lb weight necessary to form the 2.0-in. high specimen. Mold hardness of the specimen is an average of six readings, three at each end of the specimen. At low density and hardness the readings vary considerably on the same specimen because of non-uniform density. At high density, the reading will vary less than ±0.5 MH value.

To correlate specimen properties with the mold, hardness of the mold is measured. Since most molds are non-uniform in hardness, readings must be taken on the parting surface and on vertical surfaces at varying distance from the parting. As in the case of the specimen, a mold rammed to high density will be uniformly hard. The object of good molding technique is to achieve a uniform and high hardness throughout the mold. Uniform properties and behavior cannot be expected from a well-formulated synthetic molding sand or any other sand if not molded to a reasonably high, uniform density and mold hardness.

Green Strength Properties

The green compressive strength of a particular sand depends on the hardness to which it is rammed. The standard 2.0x2.0-in. AFS specimen is made with three rams of the standard rammer. This specimen provides one point on curves such as those in Fig. 1. For clay-saturated sands, the standard specimen mold hardness will usually read about 84 to 92 depending on moisture content. Its green compressive strength will correspond to the mold hardness on the upper curve in Fig. 1. For unsaturated sands, mold hardness of the standard specimen will be about 75 to 88 depending on moisture content. Green compressive strength will fall below the maximum curve in Fig. 1 depending on the per cent clay in the sand. Green shear and green tensile strengths will show similar relationships within limitations pointed out in reference 5.

The one point on the MH-GCS curve provided by the standard sample can be used as a sand control device. In clay-saturated sands, the point will always appear on the maximum curve in Fig. 1 (as long as the ingredients are behaving properly). If the clay content decreases (or mixing is ineffective), the point will fall below this maximum curve. These two properties, mold hardness and green compressive strength, provide a means of locating a sand relative to saturation or unsaturation by using Fig. 1.

Moisture content merely moves the point up or down on the curve. A control point can thus be consciously selected and variation about this point specified. For example, 14 to 16 psi green compressive strength and 84 to 85.5 mold hardness might be selected for a clay-saturated sand. This combination could be achieved only over a controlled moisture range.

Dry Compressive Strength

The dry compressive strength of molding sands is largely determined by the same factors discussed previously for green strength. One important difference concerns the effect of free water present in the sand; dry strength increases as per cent free water increases. The latter behaves directly opposite to that shown by green properties in relation to free water.

Green and dry properties may be correlated by introducing the effect of moisture. Figure 2a provides such correlation for an 8 per cent western bentonite sand and Fig. 2b for a 3 per cent western bentonite sand. Figures 2a and 2b are used in conjunction with Fig. 1, the MH-GCS curve for the same sands. The curves relate the effect of ramming (movement away from the origin on a curve of fixed per cent H_2O) and the effect of moisture content on the relationship between green and dry compressive strengths.

Figures 2a and 2b are also curves for constant ramming energy for standard three rams of a 14-lb weight and 20 and 10 rams respectively of a 2.0-lb weight dropped 2.0 in. The 2.0-lb, 2.0-in. ram imparts the same energy to the sand as does one jolt of a jolt machine with 3.0-in. table stroke (reference 16). The curves of constant ramming energy slope downward and to the right in Fig. 2a and 2b. These figures clearly demonstrate that higher properties (green and dry strength) are developed at constant ramming energy in the 8 per cent western bentonite sand than in the 3.0 per cent western bentonite sand.

Laboratory specimens and molds can be correlated by using Fig. 1 and 2 together. For example, if a mold

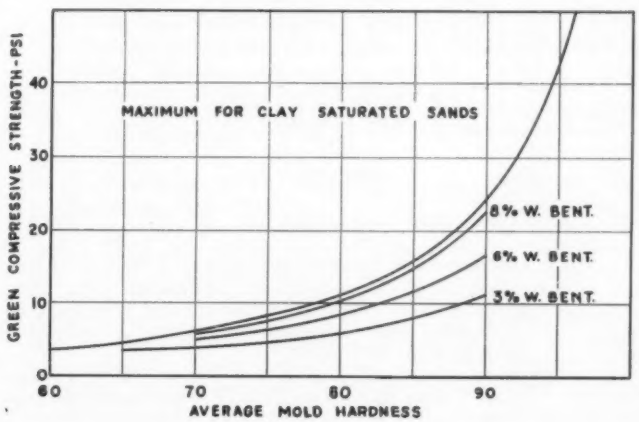


Fig. 1 . . . Effect of clay content on relationship between mold hardness and green compressive strength. Average mold hardness is obtained from three readings on top and three on bottom of specimen. The "maximum" curve applies equally well to clay-saturated sands bonded with southern bentonite, western bentonite and/or fire clay.

is rammed to 70 MH, Fig. 1 indicates a green compressive strength of 5.5 psi will develop. At 5.5 psi green strength, Fig. 2a shows that the dry compressive strength developed will vary from 0 to 60 psi, depending on per cent moisture in the sand. If the mold is rammed to 90 MH, Fig. 1 shows that a green strength of 24 psi will develop in the 8 per cent western bentonite mixture. Dry strength at this green strength coud vary from about 30 psi to over 200 psi depending on moisture content of the sand.

So an adequate dry strength can be obtained by ramming a wetter sand to lower hardness or a dryer sand to higher hardness. The best sand will not develop adequate dry strength if rammed to only 50 mold hardness. These curves illustrate the tremendous importance of the combined effects of ramming and moisture content of the sand. By controlling moisture in the ranges suggested by the calculations discussed earlier, you can obtain a suitable combination of green and dry strength.

Factors such as clay content and type, additives, base sand, molding, etc., do have effects on the dry strength developed in a sand. Some of these are discussed in reference 6. However, once you select a sand formulation, the major effects are moisture and the properties developed by ramming as discussed above.

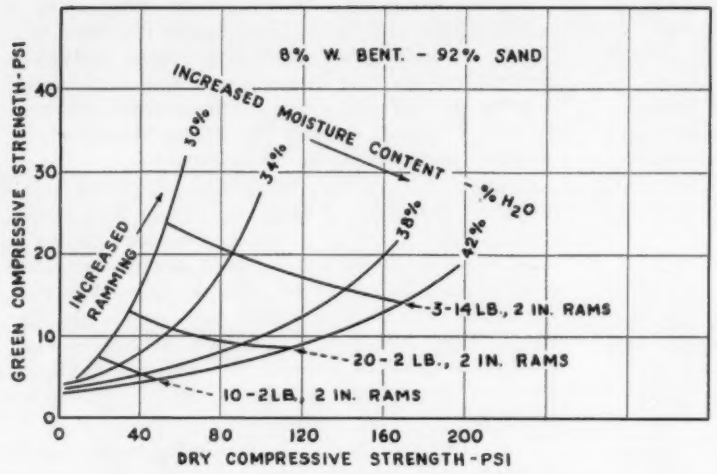


Fig. 2a . . . Relationship of green compressive strength, dry compressive strength, moisture content and ramming in an 8 per cent western bentonite-92 per cent sand of 85 AFS fineness number.[6]

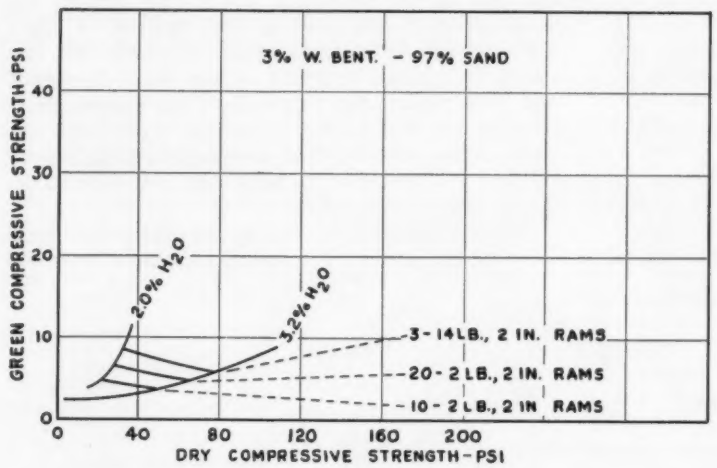


Fig. 2b . . . Relationship of green compressive strength, dry compressive strength, moisture content and ramming in a 3 per cent western bentonite-97 per cent sand of 85 AFS fineness.[6]

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Four Eminent Metallurgists Add to Wittmoser's Classification Idea

LAST DECEMBER, MODERN CASTINGS featured a learned treatise by Dr. Adalbert Wittmoser covering a proposed "International Classification of Ferrous Cast Metals". Basically he categorized all iron-carbon cast alloys into four families: 1) cast steel; 2) malleable cast iron; 3) cast iron; and 4) special cast alloys.

A common understanding in alloy terminology has national as well as international importance in scientific communication. For this reason MODERN CASTINGS has asked the four well known metallurgists pictured above for their comments which follow:

1. *Terminology needs simplified for benefit of designers and users of cast metal products.*

From the standpoint of terminology Dr. Wittmoser has done a splendid job in relating microstructure to the various cast ferrous metals which he has categorized into four simple classifications.

Although the ferrous metallurgist should have no problem in understanding Dr. Wittmoser's detailed explanation of the four classifications which he suggests, a little simplification is necessary for the average user and designer of cast metal products. For example, such metallurgical terms used in the article as "Ac3 point"; "ledeburite"; "the bainitic structure of acicular cast iron", are but a few of the points which would be confusing to most users and designers of cast metal products.

It would also be of interest and value to include the ranges of mechanical properties available with materials of the various classifications. The chart shown in Fig. 23 somewhat covers this field, but not adequately enough to choose the most suitable cast ferrous alloy for any specific application.

By incorporating these minor changes, the classification of ferrous cast metals presented by Dr. Wittmoser should be even more valuable in developing a better international understanding of the metals which he discussed.—VERNON H. PATTERSON, Metallurgical Engineer, Vanadium Corp. of America, Chicago.

2. *Confusion between nodular form graphite and spheroidal form needs further clarification.*

This classification of the technically important types of iron-carbon cast alloys by A. Wittmoser is very interesting. There are some points, however, on which the present writer fails to agree with the author.

It is not clear to the writer as to what form of precipitated graphite in iron the author understands with reference to the nodular graphite.

In describing the structure of pearlitic malleable iron he says that this iron can have its graphite in spheroidal form (Fig. 13, left) or in nodular form (Fig. 13, right—irregular patches of graphite characteristic to the black heart malleable iron).

Again in Fig. 8 and Fig. 11 he calls these patches nodular graphite. Yet in showing the structure of nodular cast iron (Fig. 16) he calls those spheroids, nodular graphite. In one case he describes the graphite patches of irregular form as nodules while in another case he also refers to spheroidal form of graphite as nodular graphite. The author seems to believe that the form of the precipitated graphite (spheroidal or patch like) does not matter. On this point the writer is in disagreement with the author. The writer also can hardly agree that iron-carbon cast alloys with spherical graphite may be "logically classified as cast steel (graphitic cast steel)."

It is known that graphite almost never forms as a primary phase in steels of ordinary composition. Sometimes it forms by solution of metastable cementite and precipitation of graphite as small nodules during continued heating in temperature regions in which graphite is stable in the presence of iron (ASM *Metals Handbook* p. 446). The writer believes that the present term "nodular cast iron" is more correct and less confusing than "graphitic steel" as

proposed by the author.—A. I. KRYNITSKY, National Bureau of Standards (Ret.), Washington, D. C.

3. *All cast metals with over 2 per cent carbon should be called cast iron. Secondary classifications would then be: cast malleable iron, cast nodular iron and cast gray iron.*

Dr. Wittmoser offers an intriguing method of classification for ferrous cast metals. Engineers and designers are not well acquainted with the Fe-C phase diagram and are much more interested in the mechanical and physical properties of the various cast metals.

Most metallurgists classify cast iron as those cast metals with total carbon content above 2 per cent. In place of putting malleable cast iron as a distinct entity, as Dr. Wittmoser has done, I would suggest that we classify all of the cast metals with a total carbon content over 2 per cent as cast iron with a secondary classification of this group as cast malleable iron, nodular iron and gray iron.

Dr. Wittmoser makes the statement that nodular iron and malleable have practically identical mechanical properties. This is not correct.

The ASTM specification A-47 covering the better grades of what we in this country consider as being malleable iron, with pearlitic malleable as another distinct entity, requires the following minimum tensile requirements:

	Grade 32510	Grade 35018
Tensile strength (psi)	50,000	53,000
Yield point (psi)	32,500	35,000
Elongation-in 2 in. (per cent)	10	18

Two ASTM specifications covering nodular iron are A-339 and A-395. The minimum tensile properties of the ferritic matrix type are as follows:

	A-339-Grade 60-45-10	A-395
Tensile strength (psi)	60,000	60,000
Yield point-0.2% offset (psi)	45,000	45,000
Elongation-in 2 in. (per cent)	10	15

It can hardly be said that these mechanical properties are identical. In actual practice nodular iron competes with pearlitic malleable iron and not the normal black heart or white heart metal. It has the further distinction of not requiring a maximum section to produce these properties.—T. E. EAGAN, Chief Research Metallurgist, The Cooper-Bessemer Corp., Grove City, Pa.

4. *Here's a classification based on graphite shapes and quantities with no recognition to matrix microstructures.*

Dr. Wittmoser has undertaken an especially difficult task in attempting to classify ferrous materials in a logical order. His subdivisions, based on carbon content and microstructure in the state of use, are logical and well defined. I can only propose that some consideration be given to mechanical properties.

It is a metallurgical fundamental that the quantity, size, shape and distribution of phases in a metallographic structure control the properties of the resultant metal. This is particularly true with respect to graphite in high carbon ferrous materials. Free graphite—regardless of its shape—reduces the load-carrying capability of a particular cross-section, since it (the graphite) has substantially no structural strength and, by its very presence, reduces the quantity of load-carrying phase in the structure.

For the purposes of the international classification, it would probably be adequate to consider only quantity and shape of graphite in separating the iron-carbon alloys into their proper families. Obviously, an increase in the quantity of graphite—regardless of shape—will result in a decrease in mechanical strength for a given matrix structure. Other properties such as damping capacity, wear resistance, heat resistance and machinability will be improved.

However, graphite shape, particularly when a comparison is made between rounded and flake shapes, has a much greater effect on mechanical properties than mere increases or decreases in quantity. For this reason, it is believed that the classifications should definitely separate iron containing a rounded type graphite from those containing flake type graphite. Also, within each classification recognition should be given to the influence of varying quantities of each type of graphite on the ready-for-use mechanical properties of the castings.

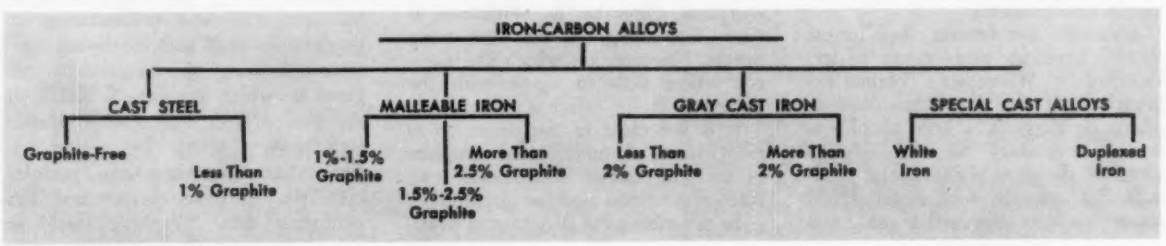
The malleable iron classification would include all irons which contain rounded type graphite: temper carbon produced in annealed white iron, duplexed particles consisting of a spherulitic center and random temper carbon as a surrounding material, and spherulitic graphite obtained by alloying with magnesium, sulfur or certain other elements.

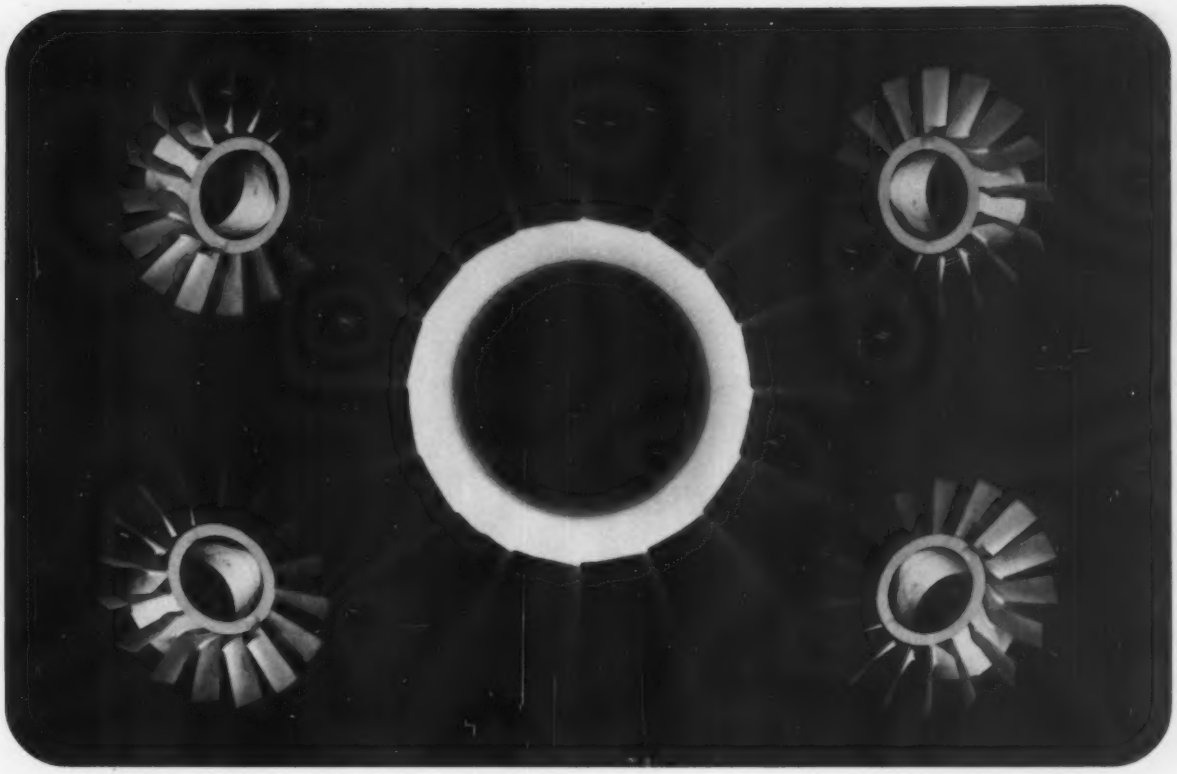
Gray cast irons would include those in which the graphite appears in the form of platelets produced during solidification of the eutectic.

It is the writer's opinion that subordinate classifications within each major classification will be required to recognize variations in mechanical properties resulting from differences in the quantity of graphite having the shape covered by the major classification. Thus, both malleable iron and gray cast iron would be covered by subordinate classes dependent upon the specific weight per cent of graphite in any particular ferrous alloy.

It does not seem necessary to provide classifications on the basis of matrix structure. Therefore, the system would be based principally on graphite structures and the presence of, or freedom from primary cementite. Provided that cast irons containing nodular graphite (as-cast) would be separated from gray cast irons under Dr. Wittmoser's proposed classifications, we would then have a system of alloys classified as shown below.

This system takes into account graphite shape and quantity, both of which have substantial effects on mechanical properties and other characteristics of iron-carbon alloys. It is understood that this gives no recognition to matrix microstructures which are controlled on the basis of specification requirements by heat treatment or alloy composition.—FRANKLIN B. ROTE, Technical Director, Albion Malleable Iron Co., Albion, Mich.





Pinwheels for an Inferno

Turbine wheels in today's jet engines face intense heat and ultra-precise operating requirements. Austenal's Microcast Division checks them for soundness with radiography using Kodak Industrial X-ray Film, Type AA

Whirling at fantastic speeds at white heat is no sissy job. It takes castings molded to utmost accuracy to stand up dependably in a powerful jet.

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Circle No. 143, Page 165

"Lost" Pattern Process . . .

New foam vaporization method bridges the gap between sculptor and foundryman.

COMBINE the amazing properties of foamed polystyrene with the ingenuity of sculptor-engineer, Alfred M. Duca, and you have a new process for converting original art into a bronze replica. The process has potential of being projected into industrial patternmaking and metalcasting operations. Its capabilities are demonstrated in the picture above. Shown is "Pegasus," a 400-pound bronze casting in the research foundry at the Massachusetts Institute of Technology, Cambridge, Mass.

The remarkable feature about this cast object-of-art lies primarily in the novel patternmaking, molding and casting techniques employed. For six weeks, Duca, a prominent Boston artist and also a research associate in the M.I.T. Department of Metallurgy, carved and filed this winged horse from a block of foamed polystyrene—a porous white plastic—the kind you see used extensively in Christmas decorations.

This material has many favorable properties—it is lightweight, rigid, strong, easy to shape with whittling tools. Density can be made to range from 1.8 to 6 pounds per cubic foot. A piece the size of a six-foot man may only weigh about five pounds.

The finished shape was completely invested by ramming up in a sand mold. Gates and risers were provided for in the ram-up. Sand was bonded with sodium silicate so the passage of CO_2 gas through the mold caused it to harden in a few seconds. Instead of the conventional practice of removing the pattern prior to pouring, this pattern stayed in the mold.

So there was no need to be concerned about back drafts or undercuts. No cope and drag parting line had to be determined. Consequently, the process has no limitations regarding complexity of intricate configurations—certainly a boon to any sculptor.

Molten bronze was poured directly into the mold so that it made direct contact with the polystyrene pattern. The 2000 F metal ignited and vaporized the plastic instantly. Gases passed out through the permeable sand mold. The molten metal filled the mold cavity which was created by the evaporation of the pattern. As soon as the metal had time to solidify, the sand was broken away—and there was a bronze Pegasus, twin of the original polystyrene pattern now lost to the ventilating system.

Not since Benvenuto Cellini combined his talents as a sculptor and craftsman to produce works of art by the "lost-wax" process in the 16th Century has there been such a major improvement in casting sculptured shapes.

Instrumental in the success of this program has been M.I.T. Prof. Howard Taylor, who met Duca at an exhibition of his sculpturing and brought him to M.I.T. to do research in casting sculpture.

Up to now most sculptures have been sent to Europe for casting. American techniques have been inferior and non-competitive. Now it is hoped the economy and simplicity of the foam varporization technique will permit foundries in this country to produce the quality of work needed.

Possible industrial applications of this process are not completely remote. Under conditions requiring only one casting, it may prove simpler to carve a complete model for burial in sand rather than construct cope and drag pattern equipment. Further economies may be realized from elimination of need for cores and affiliated core box equipment.

A further projection of this technique may lead to a process wherein multiple polystyrene pattern duplicates could be made. Possibly a flexible rubber mold could be constructed. Then the basic foaming ingredients could be placed in the mold cavity. Within a few seconds the chemicals would react and fill the cavity. Open the mold and you have a foamed-to-shape pattern ready for investing in sand. And the pattern mold can be used over again indefinitely to produce the same shape for as many castings as needed.

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Every foundryman knows how important *uniform coke size* is to a successful melting operation. Size bears a close relationship to carbon absorption, temperature rise, rate of combustion or reactivity, and to pressures.

That's why Semet-Solvay screens its five standard sizes of coke so carefully. And *after* screening, it is actually *hand-picked* to eliminate any oversized or off-quality pieces which might affect results in your cupola.

Yes, there's a size of Semet-Solvay coke just right for your foundry—it's uniform in size and quality for uniform results.

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Circle No. 141, Page 165

How to control casting quality:

use quality-controlled alloys from Reynolds Aluminum

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One good way to be sure of uniformity and high quality in your aluminum castings is to be sure of the quality of the pig or ingot you use. Many foundries have solved their quality-control problems by using Reynolds Aluminum pig and ingot along with Reynolds technical and consulting services. (You get *more* than metal when you buy from Reynolds.) High standards, painstaking production and inspection methods all assure the consistent high quality of Reynolds casting alloys.

In addition to the large stocks of casting alloys maintained at our producing plants—Jones Mills, Arkansas and Troutdale, Oregon—an important part of Reynolds service to the foundry industry is a nation-wide network of ingot distributors whose extensive stocks are even closer to you. *Reynolds Metals Company, P.O. Box 2346-FL, Richmond 18, Virginia.*

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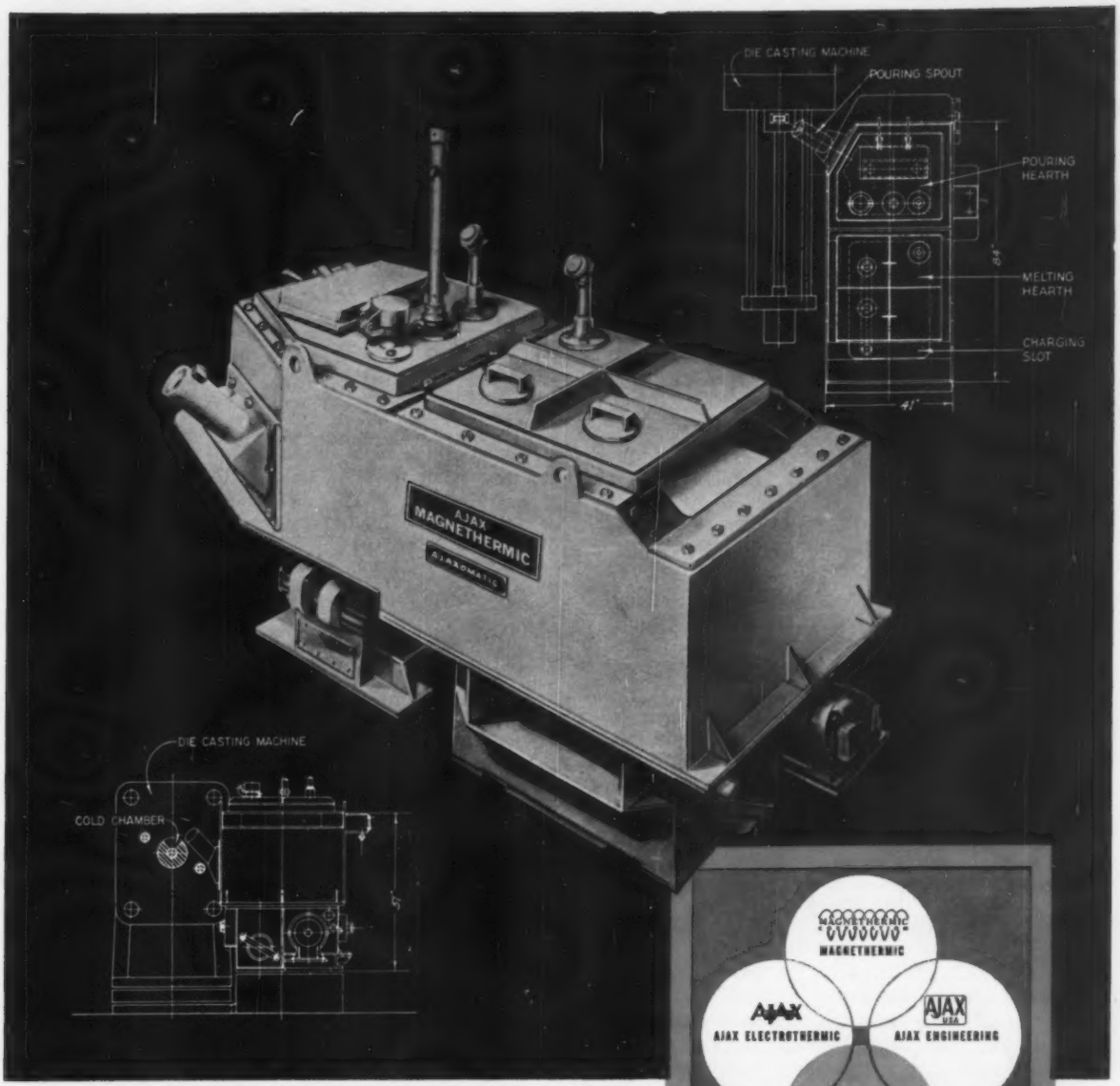
The Finest Products Made with Aluminum are made with REYNOLDS ALUMINUM

Circle No. 145, Page 165



Duplex Ajaxomatic for melting and holding metal for automatic casting operations.

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Circle No. 146, Page 165

S. C. Massari

Castings Congress Papers

Here is the 27th regular monthly Preview of Castings Congress Papers. This month six important technical articles are presented on the following subjects . . . a message to management on the future of the foundry industry, accident prevention, metallurgy of austenitic cast iron, hot compression strength of sand, casting heavy sectioned malleable iron and annealing malleable iron. The brief technical highlights that follow will help you quickly learn the significant progress unveiled in these papers.

TECHNICAL HIGHLIGHTS

Where Do We Go From Here.....p. 59
This is the 1960 Hoyt Memorial Lecture—a message to management on the future of the foundry industry. W. J. Grede, Chairman of the Board, Grede Foundries, Inc., Milwaukee, talks straight from the shoulder to foundrymen about foreign competition, unfair taxation, marketing needs, research courage and industrial survival. In general he feels that the foundry industry has spent most of its time and effort making good castings with considerably less thought and effort devoted to telling customers about developments.

Loss Prevention Through Accident Prevention..p. 65
What is safety? Safety is forethought in action. It is looking ahead to see what can happen, and then taking the necessary steps to see that the wrong thing does not happen. An accident is a signal that something has been wrong in an operation. Unsafe conditions reveal the presence of a faulty design, equipment, arrangement, placement training or operating procedure. The lifeline of accident prevention is anticipation.

Austentitic Manganese Steels .....p. 73
Improving of wear resistant manganese steels was made through carbide dispersions by a grain refinement combined with a 2 per cent molybdenum addition and a special dispersion hardening heat treatment. The treatment involves a pearlitizing treatment at 1100 F, followed by re-austenitizing at temperatures ranging from 1700-1900 F.

Nickel and Silicon Influence on Cast Iron.....p. 87
Increasing use is being made of austenitic cast iron containing 20 to 35 per cent nickel for pumps, valves, exhaust manifolds and turbocharger castings. Accurate knowledge of the combined effects of nickel and silicon on the eutectic carbon of iron is essential to its foundry control. As a result of this research a formula was developed showing eutectic carbon = 4.30 − 0.33 (% Si) − 0.047 (% Ni) + 0.0055 (% Ni) (% Si).

Effect of Ramming and Clay on Hot Strength..p. 90
This research demonstrates that increased ramming can raise hot compressive strength of any sand mix by 4 to 10 times depending on testing temperature. At constant ramming energy, maximum hot compressive strength is reached at about 6 per cent western or southern bentonite. With fireclay bond, hot compressive strength increases with increasing fireclay content until it reaches a maximum at 100 per cent fireclay.

Effect of Melt Additions on Mottling.....p. 98
This work, under the direction of the AFS Malleable Division, sponsored by the AFS Training & Research Institute, is aimed at producing heavy section iron castings without mottling or primary graphitization during freezing and still be amenable to malleablizing by heat treatment. Bismuth, tellurium, thallium, indium and zinc were added to melts and cast into 4x4x8-in. castings to measure their influence on prevention of mottling.

Effects of Melt Addition on Annealability.....p. 114
In this AFS Training & Research Institute-sponsored research, measurements are made to show the effects of bismuth and tellurium ladle additions on influencing first and second stage graphitization. Apparently these two elements have no direct effect of retarding first or second stage graphitization. Silicon content is most influential on determining time required for both first and second stage graphitization.

The AFS Castings Congress papers are the most authoritative technical information available to the metalcasting industry. Over 100 papers were prepared by close to 250 authors and presented at the 1960 Congress in Philadelphia, May 9-13. Papers receive preview publication in MODERN CASTINGS and then are bound into the annual volume of AFS TRANSACTIONS for permanent reference. All papers have been approved by the appropriate Program and Papers Committee of the sponsoring AFS Technical Division. They are then edited by AFS staff members C. R. McNeill and M. C. Hansen.

Written discussion of these papers is welcomed and will be included in the publication of the 1960 bound volume of AFS TRANSACTIONS. Discussions should be submitted to the Technical Director, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

1960

Charles Edgar Hoyt Memorial Lecture

WHERE DO WE GO FROM HERE?

by W. J. Grede

ABSTRACT

The casting industry has changed greatly in the past ten years as far as methods, materials and equipment are concerned. Many metallurgical advances have also been made, but the production of castings has not increased a great deal; production has not kept pace with the production of other competitive industries. To overcome this, there is a need for more emphasis on the advantages of the casting process, according to the author, as well as putting into production higher strength metals which have been developed through metallurgical research. Thin walled castings, new production methods to make them competitive and skilled supervisory personnel are needed in the future of the foundry industry.

INTRODUCTION

When I began preparing this paper, my mind drifted back to 1917, the year I entered the foundry business. It was in those early years that I first met the man who is honored by this memorial lecture, Charles Edgar Hoyt. The changes since then have been gradual but, when looking back, truly remarkable. Many of the terms in regular use in the foundry today were unknown, or at least unfamiliar, in our foundries then, such as shell molds and cores (Fig. 1), CO_2 molds and cores, diaphragm molding, ultrasonic testing, gamma ray testing, vacuum melting, vacuum heat treating, and a long list with which you are familiar.

These methods, materials and equipment are some of the currently essential tools which we must increasingly apply and expand the use of if our industry is to keep abreast of the rapid advances of this age. While this list may seem rather impressive, I am sure other industries, some of which are our competitors, can present an equally impressive one.

METALLURGICAL DEVELOPMENTS

The list of metallurgical developments during this time is also extensive. About the time I was entering the field, analysis by fracture was fading out and chemical and photomicrographic analysis was becoming a necessity. Nodular (ductile) iron castings (Fig. 2), magnesium castings, titanium castings, pearlitic malleable castings (Fig. 3), and many other alloys and combinations in the ferrous and non-ferrous field, practically unknown then, are now being made successfully on a broad production basis.

Our research metallurgists give us an ever expanding series of high alloy metals which are heat and corrosion resistant to an almost unbelievable degree. Steel castings are being produced regularly with a minimum tensile strength of 250,000 psi and, experimentally, with even higher tensile strength in the range of 300,000 to 400,000 psi. High strength to weight ratio steels are being used at elevated temperatures in the rocket, space travel and guided missile programs. Super alloys are operating at 1800 F for extended periods of time.

Improved low temperature metals are being produced to operate in the Arctic and Antarctic, as well as in the pumping and storage of liquid rocket fuels. These metals require high strength and toughness in the range of −320 to −425 F.

The progress of peaceful atomic energy utilization is to a large measure tied up with the advances in metallurgical knowledge and development, especially in the field of cast metals which lend themselves so admirably to the special shapes and forms required.

The problem of producing castings having appreciable tensile strengths at elevated temperatures, together with excellent corrosion resistance, is being met successfully by the foundry industry.

Filamentary Crystals

Recently I saw references to work being done in an area of filamentary crystals or "whiskers." This represents nearly perfect crystallization. Such materials are reported to possess almost perfect theoretical strength which is in the order of 1,900,000 psi for iron. Just how these astonishing properties will be utilized and, further, how they will be able to fabricate or cast these whiskers is a part of the challenging frontier ahead.

In going through the new *Gray Iron Castings Handbook,* published by the Gray Iron Founders' Society, I was impressed with the vast amount of available engineering data, such as:

1) Stress Rupture.
2) Mechanical Properties at Various Temperatures.
3) Effect of Chemistry on Mechanical Properties.
4) Stress Strain Data.
5) Endurance Limits.

W. J. GREDE is Chairman of the Board, Grede Foundries, Inc., Milwaukee.

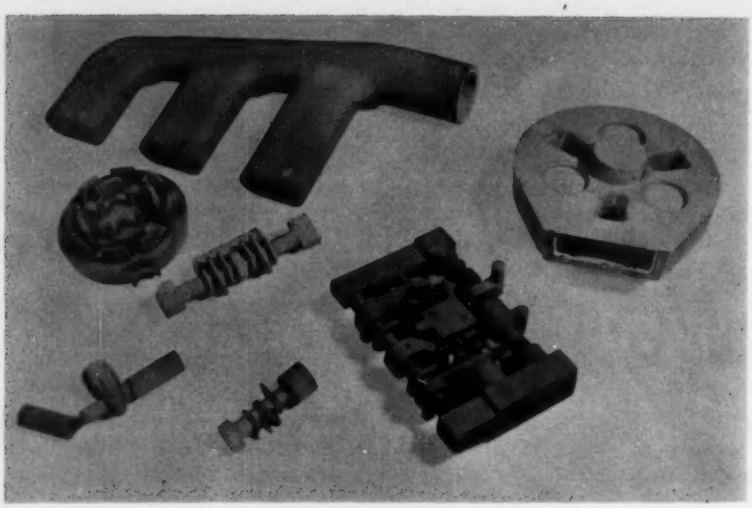

Fig. 1 — Shell cores.

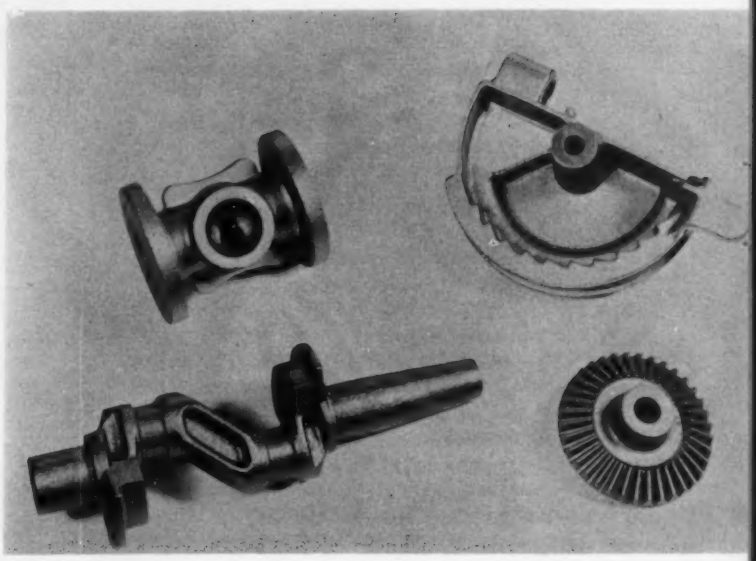

Fig. 2 — Ductile (nodular) iron castings.

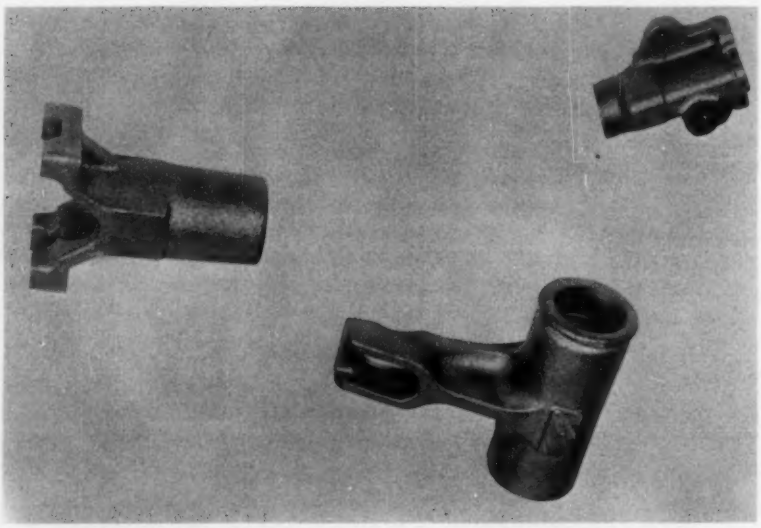

Fig. 3 — Pearlitic malleable castings.

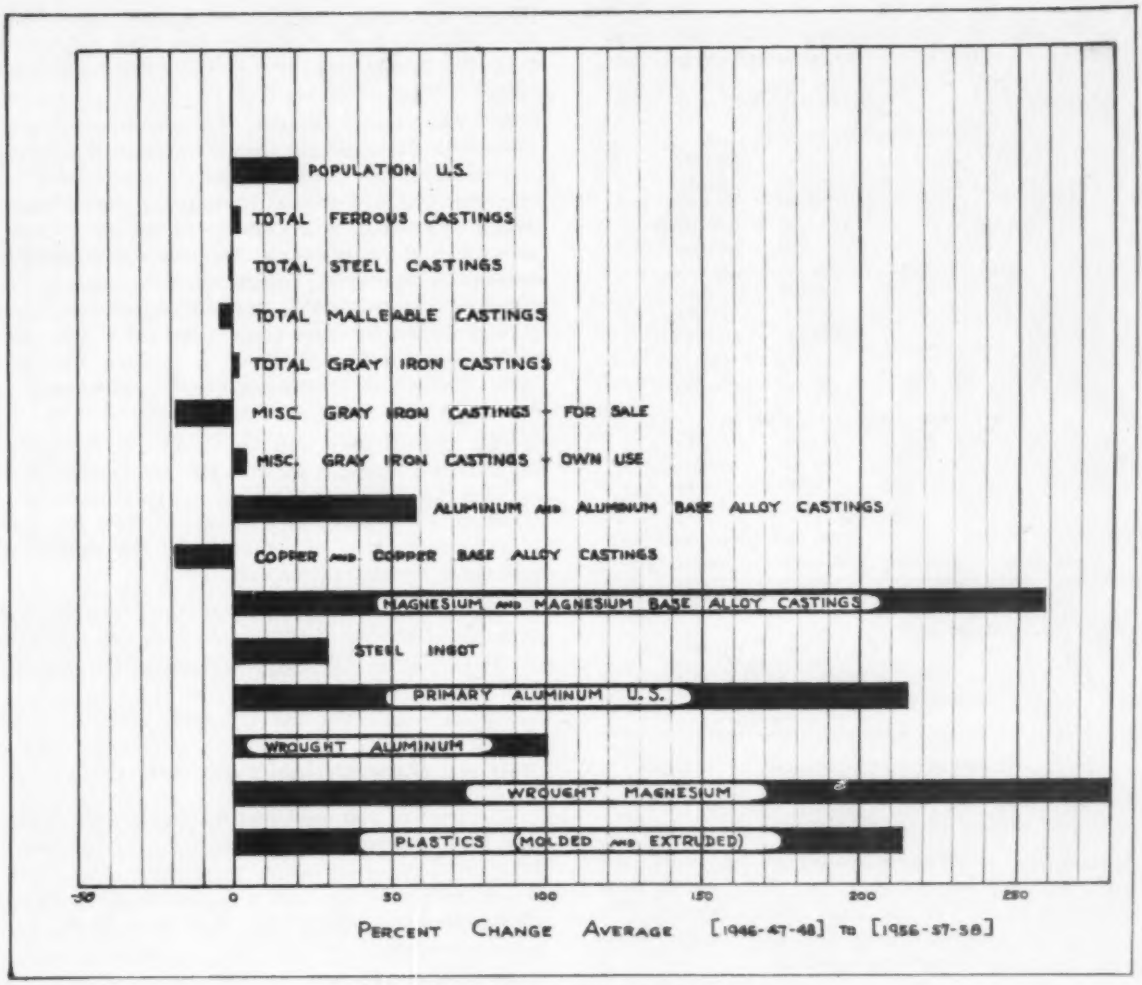

Fig. 4 — Production comparisons of a decade ago.

6) Impact Strengths.
7) Wear Resistance Data.
8) Corrosion Resistance Data.
9) Creep Rupture Data.

These are but a few of the tables and charts in this book. Similar data are available for the other cast metals.

With all this engineering information readily obtainable, the design engineer can design parts with a much higher degree of certainty and more dependably select the best material for a given set of operating conditions.

PRODUCTION COMPARISON

The statistics in Fig. 4 indicate production comparisons of a decade ago. When making comparisons of any kind, it is almost impossible to select a basis which is completely representative for all matters under consideration. When this paper was being prepared, the latest complete available annual statistics were for the year 1958.

I decided, therefore, to average the last three available years — 1958, 1957 and 1956 — and compare these data with the average for a similar three-year period ten years prior — 1948, 1947 and 1946. The units of comparison were castings produced and sold in tons or lb. Tons or lb units were selected because, as far as I know, these particular units of measurement have not yet been affected by inflation.

I considered using the dollar-unit, but unless adjusted for inflation over even a short ten-year span, the figures would not be reliable statistics. One ton is still a ton, but with what is going on not only in America but in other parts of the world as well, it may not continue to be. While this paper is being presented before a technical group and you would expect, therefore, that it would include largely technical material, "Where do we go from here?" will be most seriously affected by what we and other na-

TABLE 1

		Avg. 1946-47-48	Avg. 1956-57-58	Change Over 1946-47-48, %
1.	U.S. Population	144,048,000	172,714,000	20
2.	**Ferrous Castings in Tons**			
	Total Gray Iron	12,077,000	12,299,000	1.8
	Misc. Gray Iron[A]	8,017,100	7,402,400	(8)
	For sale	3,973,500	3,205,400	(19)
	For own use	4,043,700	4,197,000	4
	Heavy Ingot Molds	1,775,100	2,305,900	30
	Chilled Iron Car Wheel	743,700	343,500	(54)
	Pressure Pipe and Fitting	991,800	1,458,600	47
	Soil Pipe and Fittings	548,900	788,200	44
	Total Steel	1,614,500	1,606,400	(0.5)
	Total Malleable	864,000	825,200	(4.5)
	Total Ferrous Castings	14,555,500	14,730,600	1.2
3.	**Non-Ferrous Castings in 1,000 lb**			
	Alum. & Alum. Base Alloys	442,700	699,300	58
	Copper & Copper Base Alloys	1,059,300	860,400	(19)
	Magnesium & Mg. Base Alloys	8,700	31,200	258
4.	**General**			
	Steel Ingot in Tons	80,045,400	104,395,000	30
	Primary Alum. (U.S.) Tons	534,900	1,630,700	205
	Wrought Al. in 1,000 lb	1,396,400	2,720,000	95
	Wrought Mg. in 1,000 lb	5,770	22,010	280
5.	Materials for Molded and Extruded Plastics in lb	Est. 473,000	1,489,000	214

NOTE: A. All Gray Iron Castings Exclusive of Ingot Molds, R. R. Wheels, Pressure Pipe and Soil Pipe.

tions do about our fiscal policy and the Government's interference in our business.

During the comparison period of ten years, our population has increased 20 per cent, more than 172,000,000 people in the 1958 census figures. The overall production of ferrous castings remained practically constant during this interval.

Gray Iron Data

The statistical data for gray iron is divided into seven classifications. These data indicate that for the type of castings made by most of the gray iron foundries represented in this room, namely, "Miscellaneous for Sale," production has decreased by 19 per cent. It is the increased use of ingot molds, pressure pipe and soil pipe that has kept the overall gray iron production about constant during this ten-year period (Tables 1 and 2).

TABLE 2

	Vol. of Castings Produced, Cu Ft		
Metal	Avg. 1946-47-48	Avg. 1956-57-58	Change Over 1946-47-48, %
Gray Iron	54,800,000	55,800,000	1.8
Steel	6,610,000	6,580,000	(0.5)
Malleable	3,820,000	3,640,000	(0.5)
Alum. & Alum. Base Alloys	2,560,000	4,120,000	61
Copper & Copper Base Alloys	2,040,000	1,650,000	19
Magnesium	76,000	274,000	260
TOTAL	69,906,000	72,064,000	

A further factor affecting the gray iron merchant foundry is the trend for castings to be made by captive shops. In the 1946-47-48 period, the ratio of captive tonnage to the total tonnage in the "Miscellaneous" classification was about 50 per cent; that is about half the castings in this group were made in noncaptive foundries. During the 1956-57-58 period, this had changed to 43½ per cent. All of the decline was in "Miscellaneous Gray Iron (A)," and more took place in the merchant or jobbing foundries. Those making their own increased their tonnage by 4 per cent.

This growth may well be all in the automobile industry, the statistics are not classified enough to determine this. I am not aware of any great trend of increase in the captive foundry population, but there is a definite trend of reduction in the number of jobbing or merchant foundries.

Between 1947 and 1959, an estimated average of 80 gray iron foundries closed each year, for a total of about 965 of the 3,068 gray iron foundries operating in 1947.

Steel and Malleable Iron Data

The level of cast steel and malleable iron production has remained about constant during this period in spite of the increase in population. The competition from, and the expanded use of, other materials has no doubt affected the production of all of the ferrous castings.

An item which may have a substantial effect on the gray iron casting tonnage of the future is the possible ultimate adoption of the aluminum automobile engine. Because most automobile engine castings are produced in captive foundries, this may not so seriously affect the jobbing or merchant foundry industry. The policy of automotive manufacturers seems to be that when a plant or process ceases to be needed the available facilities are converted to other uses, rather than to continue operations and enter into competition with outside producers of similar nature.

Foreign Competition

A number of times in my traveling about, I have been asked for my opinion of the effect of foreign competition on the foundry business. I have been unable to find that as yet there has been any substantial import of castings as such into this country. As foreign economics improve and their standards of living and wages adjust, the margin will narrow to the level of their productivity, and with a product like

castings I do not look for any substantial competition from overseas.

We cannot overlook, however, the impact of the finished product upon our casting market. I refer to such things as the importation of automobiles, electrical machinery, machine tools, tractors and agricultural equipment. These are all large consumers of castings. During 1958, we imported $28,000,000 of machine tools, $86,900,000 of electrical machinery and $486,800,000 of automobiles. Just how many actual casting dollars these represent is difficult to evaluate, but you can be sure it is substantial. Where this will end is difficult to say.

As the European economy grows it will demand more and more of its own production, and its costs could well build up to match ours. In the meantime, American manufacturers and foundries too must exert every effort to improve practices, quality and costs to meet this competition; and if we can keep our economy and our people free, we will to the benefit of all our people.

Light Metals Data

The position of the non-ferrous light metal foundries is much more favorable in this comparison period. The combined aluminum and aluminum-based alloy casting production increased approximately 58 per cent. Magnesium and magnesium-based alloy casting production increased 258 per cent during this period. However, the copper and copper-based alloy casting production declined 19 per cent.

It is realized that to add the total of all casting production together may not be entirely above question. However, I have done this and during the 1946-47-48 period a total of 15,310,000 tons of castings were produced. While in the 1956-57-58 period, a total of 15,526,000 tons were produced, or an overall increase of only 1.5 per cent. Even after adjusting for the variation in specific gravity, the total volume of casting production went up only 3 per cent, as compared with a 20 per cent increase in population.

OTHER INDUSTRIES

Now what happened to some of the materials which can be considered competitors of ours? Ingot steel production increased 30 per cent during this period, primary U.S. aluminum production increased 205 per cent, wrought aluminum 95 per cent and wrought magnesium 280 per cent. Materials for the production of molded and extruded plastics increased 214 per cent during this ten-year interval. The use of ferrous and non-ferrous metals other than cast increased in tonnage during this period a total of 32.6 per cent.

This indicates that the foundries lost out to other means of fabricating in these same metals, to say nothing of the inroads of plastics. Every foundryman faces the challenge of improved techniques of production, metal and design to recapture this market.

Why is our output substantially static? What can we do to change the condition? There are things to be done if we are to stay solvent and remain an important industry. Recently we replaced a heating boiler in one of our foundries. I well remember when the old boiler was put in operation, it cost about $10,000. To replace it will cost $50,000. This demonstrates how fast we must run to accumulate the necessary capital just to stay in business.

With the present tax structure, how are we to accumulate the capital so necessary to keep our plants intact, to say nothing about keeping them abreast of the times. Dimensional precision and better chemical and metallurgical control require new and improved production and laboratory equipment. The equipment is available, but how can we accumulate the necessary capital?

The progressive individual income tax structure and the high corporate tax severely penalize the productive. It is called a "soak-the-rich" tax, but it is in fact not related to how much wealth you have, because an estate of tax-exempt securities could well pay no tax. It is related, however, to how productive you are. Those that produce most and create the largest income are penalized the most.

Unlike American business that rewards the productive, our Government penalizes the productive. This plagues all American industry and, therefore, there are some skills and techniques, as well as some substantial effort that we must develop outside of our technical problems and in the area of public and political relationships.

PUBLICITY NEED

The aluminum industry, the steel industry and the cement industry are constantly broadcasting the merits of their product to the public and to the engineer and designer. This is an area the casting industry as such neglects, one in which I feel we must enlarge our activities. A concerted drive by all of the casting producers, individually and through such a group as the National Casting Council, to broadcast the merits of our particular manufacturing process, is seriously needed if designers, engineers and users are to be alerted to the relative merits of castings in certain designs.

The casting process is a process whereby the most effective properties of a particular metal can be applied and utilized to the greatest degree possible.

Mill produced structures and shapes, such as beams, angles and plates most generally have of necessity uniform cross-sections in one direction. When these uniform sections are fabricated into a structure, the maximum utilization of the metal section is not always attained. In the casting process, heavily stressed sections may be readily enlarged, and lightly stressed sections may be decreased in size or thickness with ease. The casting process alone affords this outstanding advantage.

Castings Advantages

We must emphasize this fact to designing engineers. We must point out to the casting buyer or de-

sign engineer the fact that by changing the section size to more effectively use the metal we can also reduce the weight of the casting, and thus reduce the weight of the assembled product. There is a definite lack of published information as to how to properly design a casting from the stress and usage viewpoint. Basically, our textbooks and engineering formulas are for the most part based on uniform sections such as are produced by the rolling mills.

Several of our AFS divisions are making a start in this direction. It seems to me that all technical and trade societies interested in the foundry industry should join with AFS to produce a textbook of this kind. The Steel Founders' Society, the Gray Iron Founders' Society and the Malleable Founders' Society have published excellent books which, in the main, deal with the mechanical properties of their specific metals.

The design book I have in mind should deal primarily with the engineering design of castings from the viewpoint of getting the most efficient use of the metal by selecting design shapes best suited for the ultimate use of a part.

It should emphasize the properties and advantages of our process, rather than a particular metal. If this is done, I am sure the most advantageous metal for a given job will be selected. A job well done along these lines would benefit the entire industry.

Generally speaking, I think in the past the foundry industry has spent most of its time and effort making good castings, considerably less thought and effort have been devoted to telling the customers about our developments.

Our sales engineers must know the foundry process and really understand its advantage to develop the maximum use of castings.

INDUSTRY CHALLENGE

Technical development proceeds at a rapid pace. New demands on metals of all kinds challenge all industry and especially our industry to speed up and broaden its research programs.

We have found that by pooling our efforts and exchanging our information we have all made more progress. Therefore it is incumbent upon us to support our technical societies (our AFS) as well as those representing the various branches of our industry. Through the combined support of these nongovernmental technical societies, as well as the developments in our own plants through the competitive urge, we will advance our whole industry.

I would urge the technical divisions of these societies to keep a bold and venturesome viewpoint. The technical societies' staffs should be urged by their Board of Directors to have the courage to enter into little known fields and select projects for investigation which may only have a fair chance to succeed.

Research Necessary

Our age has been accused of a "failure of nerve" with the result that our goal has become one of security. The type of research necessary for the solution of our problem cannot flourish in an atmosphere which emphasizes security. Good research must, by its nature, always encompass a large element of uncertainty. If we can rest secure in the success of our work then we are not doing real research. We are instead, simply refining old methods and materials already known to be reasonably successful.

We must urge our technical and research groups to have a dynamic approach to our problems and to have the courage to fail. They must also have the dogged determination never to stop searching for a solution no matter how often they may fail in the attempt.

Data Utilization

As previously stated, I think we have done an excellent job metallurgically in advancing our industry. It seems to me we have not progressed as much in the less glamorous field of molding, with special reference to utilizing some of the metallurgical information obtained. It appears to me, if we are to gain full advantage of the higher strength metals that our metallurgical research has developed, we must be able to produce our castings with thinner walls, thereby reducing the shipping weight and metal costs, thus putting ourselves in position to better meet our customers' needs.

I would like to urge our technical and operating people to attack this problem from two viewpoints. First, to produce mold surfaces which offer less resistance to metal flow in thin sections. Second, if we are to produce thin wall castings a great deal of shop effort must be placed on developing our ability to make molds and set cores in such a way as to insure thin wall sections on a repetitive basis.

There is no use having a metal which readily flows into thin sections if we cannot set our cores to consistently produce thin walls. To do so may require some drastic revisions, both in our molding and our core-making methods.

Develop New Methods

After these new techniques and methods are developed, to be of value they must be put into daily production. This requires a skilled, informed supervisory staff in all departments of our shops. In this connection our foremen must be well trained in all phases of their job. I commend the American Foundrymen's Society on their Training & Research Institute program. This and similar institutes in allied fields will go a long way to help our supervisors keep abreast of current advances and to effectively utilize the new techniques and developments.

The work of the Foundry Educational Foundation has given status to our industry in the engineering training field at the college and university level.

There are some discouraging aspects about certain portions of the foundry business. If we approach the future with enthusiasm and vigor, I am sure that we will survive and grow.

LOSS PREVENTION THROUGH ACCIDENT PREVENTION

by George A. Riley

ABSTRACT

The first section is a brief description of the author's company's Accident Prevention program.

Two stories of actual cases are used to show the vast difference in compensation values of years ago and today; and also to highlight the company's regard for moral as well as legal responsibility.

The theme is stressed that "accident costs are operating costs" and can be kept to a minimum by accident prevention.

The second section is composed of charts, photographs and other illustrations to show "how to" and "how not to" have a good accident prevention program.

INTRODUCTION

One usually opens a talk by telling a funny story or two. I have a couple of stories, but they are not funny. However, they are true.

The first one began away back on Nov. 9, 1907, when a boilermaker's wife gave birth to her twelfth child. On Dec. 10, 1907, one month later, that boilermaker was killed. He was crushed between two freight cars being coupled in the yard of the railroad shops where he worked. His helper was fired because he refused to sign a statement placing full blame on the boilermaker.

What compensation do you think that widow would receive today? What compensation do you suppose that widow actually received?—$1700—and $700 of that came from contributions from fellow employees. The company's lawyer persuaded the widow to settle out of court for $1,000.

A TWO MINUTE JOB

The other story is this: On Feb. 8, 1949, a master mechanic at one of the author's company's foundries was passing a mud mixing mill and he noticed that the housing was a bit loose. This mill was of simple construction—a v-belt drive from a motor turned a shaft which had a pinion gear meshing with a large circular gear that had a shaft extending down, and the mixing pan with the wheels and blades was below, about waist high. A push button control was suspended in front.

The master mechanic climbed up on the housing, checked it and found a stripped bolt. He told his helper to go get him a new nut and bolt. It was reported that the helper told him he "better lock out the main control switch." The master mechanic said, "Never mind, this will only take 2 min."

The helper left to get the nut and bolt, and the mechanic stood astride the big gear. As he stood there, the operator walked over right in front of him and pushed the button and started the mill. The mechanic was thrown into the gears. Suffice it to say the mechanic lost one leg below the knee, and was given one chance in a thousand to live through the night. He made it and he is still living, and was still on the plant payroll up until his retirement two years ago. His knowledge of the plant carried him. He had worked at the same plant for 40 years and reported daily to oversee the maintenance work, but he never finished that two minute job.

How much has the case cost the author's company? Just about $25,000.

Draw the lessons from these two stories.

I know personally what the loss of the boilermaker meant to his widow and her children. I saw the struggle and the hardships that mother had raising that family. I know what accidents can do as I was that boilermaker's twelfth child.

COMPANY ATTITUDE

Take the attitude of the companies involved. The boilermaker's employer deliberately avoided paying what morally he should have paid, while the author's company, in the case of the master mechanic, did everything within its power to help the injured man. One of the best specialists in the country cared for him. There was never any attempt to intimidate the man nor his helper.

In other words, the company felt morally obligated to do all that could be done to help. Following the compensation law the company could have gotten off much cheaper, but there is also the company's moral obligations as employers.

You may be saying: "This company is supposed to show how costs can be cut through an accident prevention program, and here it is admitted that the program failed in one case to the extent of $25,000." In other words, why have a safety program if you are

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still having accidents? The question is a simple one, and answered by another question. Do you do away with the fire department because you had a conflagration? Do you say to do away with traffic lights and traffic regulations just because there are still automobile accidents? No, you increase your efforts to prevent fires and automobile accidents.

That is exactly what the author's company has done. Efforts have been and it has definitely shown that it pays off.

SAFETY RULE VIOLATED

Before going into that phase let us consider the rule which the master mechanic violated. The rule reads: *"Whenever you have to work on any equipment you must lock the main control switch in the off position and keep the key to that lock in your pocket."*

The author's company is constantly checking on this. As you all know, certain equipment such as mixers, mud mixers, pug mills, and others have to be periodically cleaned or blades changed or repairs made.

This reply came from one mixer operator when reminded about locking out the switch before he cleaned it. He said: "I cannot do that because I clean it after every batch, and besides this is only a small open job and everybody can see me cleaning it." The reply given him was something like this: "Put your arm in there and we will push the button." He naturally objected. So he was told "You know there are still a lot of foolish people in this world who would push that button just to see what would happen? You had better lock it off each time just to be sure." He said he would.

There is value to safety regulations. If our master mechanic had followed safe procedure he would be a whole man today, and that $25,000 could have been used elsewhere.

SAVE MONEY THROUGH SAFETY

The point of all this is to see how to save money through the safety program.

How is it done? By showing plant managers that accident costs are operating costs, and if they put more emphasis on how to prevent accidents they could cut those costs thereby lowering their operating costs. Everyone in the company is striving for lower costs, and accident costs are absolute waste.

Also, the company de-emphasized the concern over lost timers, and put the emphasis on the elimination of accidents. The seriousness of an accident is mostly a matter of chance anyway. The master mechanic could have been thrown clear when that fellow started the machine.

The company is striving to prevent *all* accidents, and that also means those that do not result in injury.

Accident Prevention Program

What is the program? It is the standard committee type of program similar to the ones used by large corporations. The author's company is not a large corporation, but it is felt that if these big corporations can see the value in a safety program, then so can we.

In the small plants there is one safety committee composed of the plant manager, his foremen and representatives from each department in the plant. In larger plants there are three committees; one, made up of the manager and his supervisors, is known as the staff committee. The other two, one for the day shift and one for the night, are composed of employees representing the various departments. These committees meet on schedule once a month.

In addition to these committees each foreman has in his department a departmental committee composed of himself and two or three of his men who police, so to speak, their own departments. Also, each foreman is expected to informally discuss some phase of accident prevention individually with each of his men during each month. This is highly important. However, if the foreman is not sincerely interested in the safety efforts, this is waste. Furthermore, if the foreman is not sincerely interested in safety, he is not a real foreman.

Inspections

Inspections are conducted by the person in charge of safety at each plant, along with the maintenance foreman and one or two of the employees selected from the committees. These inspections cover the whole plant. Special inspections are made of chains and cables, safety glasses, safety shoes, fire fighting equipment, ladders, grinding wheels and the locks and keys supplied for locking out switches by maintenance men and others whose duties require them to clean or adjust equipment.

Also, accidents are investigated. Yes, the company still has to contend with accidents, and no doubt will continue as long as human beings are around. These investigations are made for one purpose—to learn the lesson the accident should teach. In other words, to find the cause of the accident and do the best possible to eliminate the possibility of a recurrence.

It is not to find out who is to blame; that is too easy, and fruitless. It is based on these questions, the same ones a good reporter uses—who did what, when, where, how and why!

That *why* is the crux of accident prevention work. If the why of the accident is not known, how can we prevent a recurrence?

"A Place for Everything"

Good housekeeping is the foundation of a good program. A place for everything and everything in its place may sound trite, but it is the only way to have real good housekeeping.

There is no mystery about keeping a place clean. If only each one would keep his particular work area clean, good housekeeping would be routine.

Industrial Hygiene Program

In addition to the safety program, there is a medical and industrial hygiene program. All employees have pre-employment physical examinations, and periodic check-ups with chest x-rays. All plants are sur-

veyed periodically by the Industrial Hygiene department, assisted by the industrial hygienists from our insurance carrier. Many persons may say this is too elaborate a setup, but it is believed that a strong safety, medical and hygiene program is not only something that companies owe their people, but also something that turns in a profit for the stockholders and owners through the development of better human relations and lower operating expenses.

When an accident occurs in your plant and an employee is injured, do you consider it an operating cost? Do you begin an extensive and intensive search for the cause or causes of the accident? You should if you wish to cut costs.

Since the majority of the author's company's plants are small, there is no physician at the plants, but there are designated physicians to handle accident cases, usually on a per case basis. However, the medical program arranges for a nurse at each plant. The company has its own staff of industrial hygienists and technicians.

SMALL PLANT PROGRAM

Small plants in a community could pool their resources in setting up a program, sharing the services of a physician or a clinic; and even hire a nurse to share her time, say among three plants. The author's company does that in some communities.

You could run your program on a cooperative basis. Make use of all local sources of information, safety councils and associations. There are many ways to get assistance in accident prevention work. There are consulting safety engineers who could be employed on a part time basis to help.

The company's safety performance record is calculated on a somewhat different basis than the one used by the National Safety Council and local safety councils. The reason for changing the system, and rest assured it is much stricter than the systems set by the organizations just mentioned, was to give an honest picture of how the plants, divisions and company were doing in relation to actual costs.

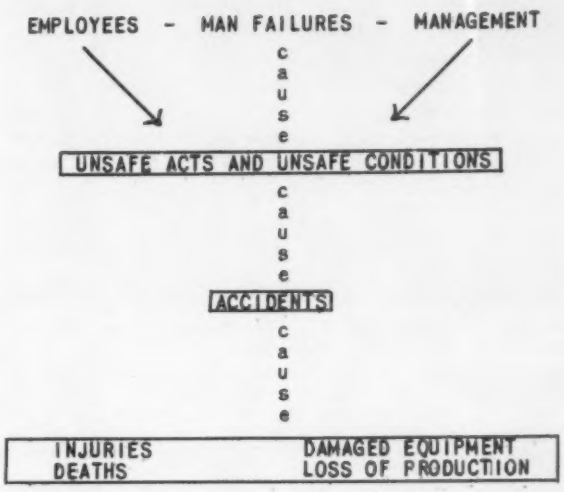
In other words it was found that a lot of little or minor cases can mount up costs. Thus, the company based accident frequency on all cases, not on lost-timers alone.

It is known that the safety, hygiene and medical program is paying dividends. The amount of money that is saved is in black and white and is known as "out-of-pocket" expense. Expenses and costs resulting from such a program as they appear on the company books do not tell the complete story. For example, it is known that every dollar paid out for every accidental injury is not the only cost assumed by the company.

There are many intangibles involved, each of which when related to over-all operations, bears a dollar sign. The experts have calculated this intangible and indirect cost to be four times the direct cost. If this is true, when a dollar of expense or cost is saved because a program such as this has prevented an injury or disease, then with the same reasoning the company has saved indirect and intangible costs in a like ratio.

Some of the plant managers were what we call after-the-fact boys. They were more concerned about what to do after the accidents occurred, than they were about preventing them. They have been convinced that it is better to put their efforts into preventing accidents rather than trying to cut costs after the accident.

TABLE 1 — BASICS OF ACCIDENT PREVENTION



All of us want safe plants and safe workers. Wanting and *willing* are two different things. If you *will* something, you want it enough to do something about it. So it is with accident prevention.

WHAT IS SAFETY?

Safety is forethought in action. It is looking ahead to see what can happen, and then taking the necessary steps to see that the wrong thing does not happen (Tables 1, 2 and 3).

A good safety philosophy is:

1) A firm belief that all personal injuries can be prevented, and should be prevented.

TABLE 2 — WHAT TO DO ABOUT MOST ACTION BEING "AFTER THE FACT"

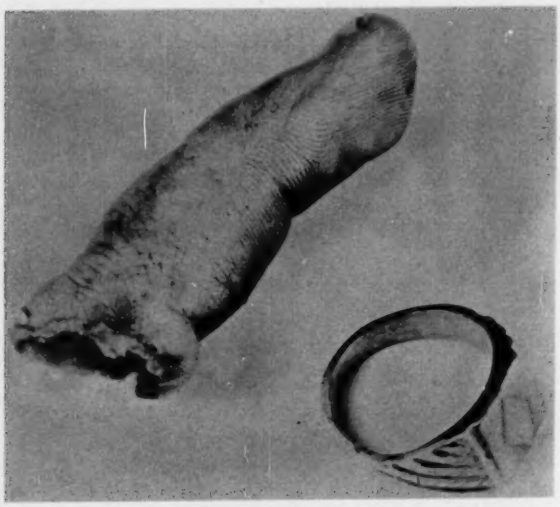
Observe	Conditions
	Unsafe acts
Emphasize	Good housekeeping
Make	Inspections
	Investigations of accidents
	Recommendations

TABLE 3 — TEN BASIC SAFETY RULES

1) Know your job thoroughly, including its hazards and safeguards.
2) Make the correct way habitual.
3) Use all protective equipment and guards required by your work at all times.
4) Think ahead to know what can happen, and then avoid the undesirable.
5) Be your brother's keeper, too.
6) Keep your mind on your job — always and all ways.
7) When in doubt, ask your supervisor or foreman anything pertaining to the job.
8) Learn the basics of first aid treatment.
9) Make safety your first consideration in all activities.
10) Promote safety at all times — it may help promote you.

2) The conviction that it is possible to safeguard all operating exposures which may result in occupational injuries.
3) An understanding by all employees that it is to their own advantage as well as to the company's to work safely, and that they are expected to cooperate to that end.
4) A recognition that active alert safety conscious supervision from top management to foreman or supervisor is a vital factor in carrying out the safety program.
5) The acceptance of the fact that prevention of personal injuries and accidents is good business from the standpoint of humanity, efficiency and economy.

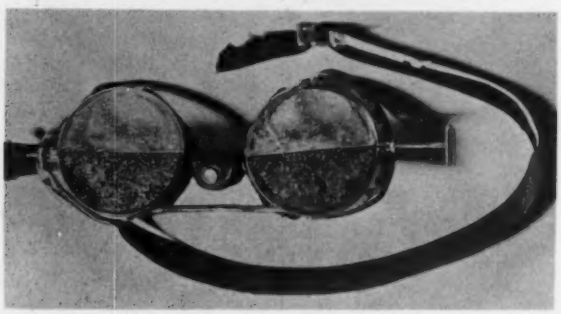
This finger was cut off because of the ring pictured with it. The former owner of the finger was operating a drill press



when the ring caught in the drill. Once up the drill was enough to do a fairly neat amputation job.

How did this one occur? He climbed up on some metal shelving. In jumping down, his ring caught on a protruding bolt. He hung there momentarily, but fortunately a fellow employee came to his rescue and saved him from losing his finger completely.

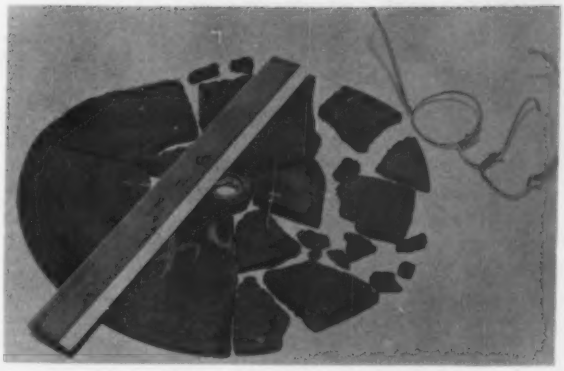
This shows the real value of wearing safety glasses. It is from a fuel and iron company. This man got the full force of a metal splash, but his eyes were saved by safety glasses.



Here are the safety glasses that saved his sight. Through prompt, correct first aid and the results of modern medical treatment, this man showed almost complete recovery a few short weeks after the burn.

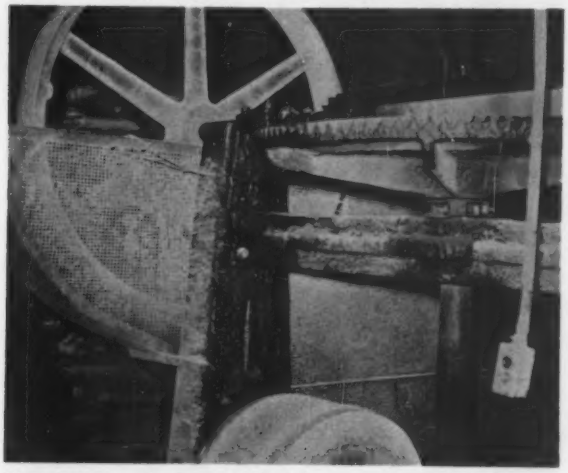
Here is one right practice and two wrong ones. The person was right in wearing his safety glasses under his welders helmet, but wrong in wearing the rings.

There is nothing particularly spectacular about this man exhibiting a cracked lens in his safety glasses — except that he was operating a crane some 60 ft over the operations. The author's company advocates 100 per cent protection throughout all plants.

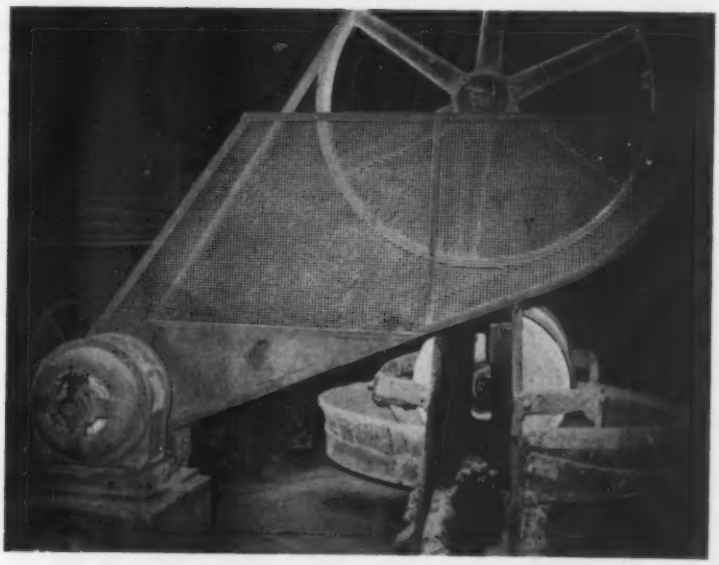


Here is a case of lack of supervision, lack of training and improper protection. The man who was using this wheel lost an eye. He was grinding a casting with a portable grinder that was limited to a 6 in. wheel and decided it was too small. He helped himself to the one pictured — 11 in. The wheel exploded in his face, and the spectacle-type safety glasses could not stand up under the impact.

The wheel on a portable grinder one worker was using broke. Note the hole through the face shield. It is not recommended that face shields be used for grinders. The workers must wear safety glasses too.



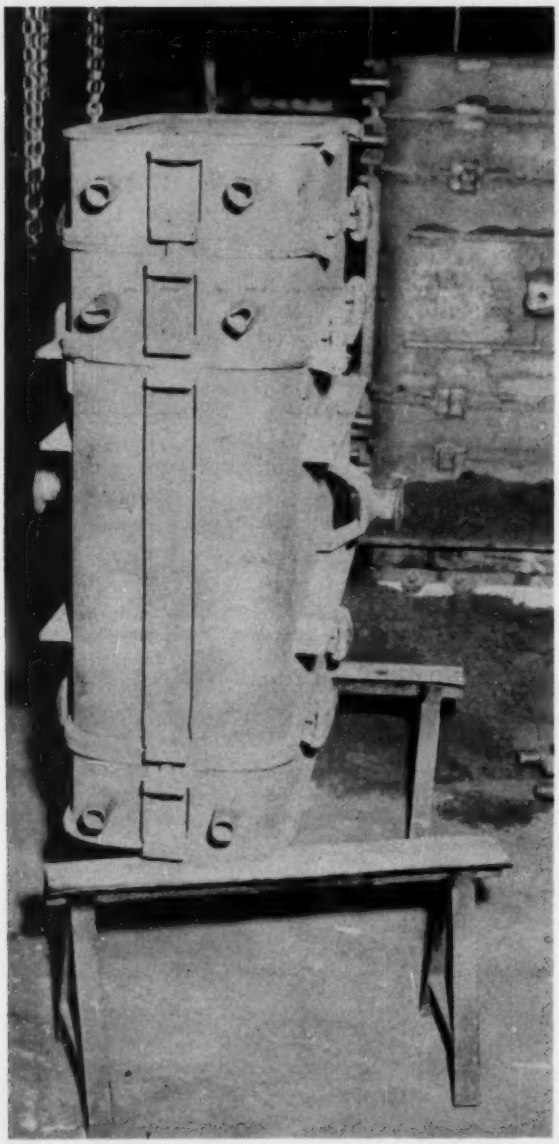
Here is the mud mixer mentioned previously. Notice the push button. The master mechanic stood astride the large gear. He could have kicked or pulled the switch away from the operator.



This is a general view of the "harmless" mud mixer.

This tag (left) could have prevented the accident, but a lock out device is more effective.

Here is the main switch (right) to the mud mixer — not thrown or locked off.



Here is an accident about to happen, and a fatal one. Notice the precarious position of that mold on those horses. This was the last mold the worker was to finish that day. It proved to be the last in his life. Earlier he had been warned that the horses should be kept straight, but —

this is an enactment of what happened. As the molder went to get down to adjust the core from the bottom, he must have jolted the mold enough to spread the horses and allow the mold to topple over pinning him against the row of completed molds.

The normal procedure in making a mold of this type is:

1) Empty flask set on bumper machine.
2) Place pattern in flask.
3) Fill flask with sand and bump.
4) Remove flask from bumper, turn it over and set flask on the floor.
5) Draw pattern from flask.
6) Place core in mold.
7) Split mold by separating cheek from the drag.
8) Place cheek of mold on steel horses which are approximately 14 in. high.
9) Check core by feeling underneath.
10) The cheek is then removed from the horses and replaced on the drag; mold is clamped and placed to be poured.

Here is how accident prevention worked to keep that type of accident from happening again. The horses were welded to flat bars to prevent their moving. Better guides were added; guide pins improved. Hooks were added to the sides. And, finally, though it is not pictured, a piece of stainless steel was placed across the bottom. Now the molder does not have to feel to see if the case is positioned properly, the stainless steel acts as a mirror, and he can look down and see up into the mold.

PRINCIPLES OF ACCIDENT PREVENTION

Accidents which have occurred disclose upon investigation that some of the conditions were not as they should have been, and that one of these conditions may have been the proximate cause of the accident. From this knowledge three lines of action are possible, and the result obtained in each case is of a different order.

1) If steps are taken to remedy the given condition which has caused an accident, thus aiming to prevent recurrence of that accident, such action is a single procedure of correction.
2) If the faulty condition is searched out in all like or similar operations, and all are brought under control, that action is both corrective and preventive.
3) If knowledge of accident causes and their preventive measures have been derived from other experience, and operations are made safe before accidents occur, the action is entirely preventive.

Action taken to achieve correction only is hindsight; to achieve prevention is foresight. Many accident causing conditions can be controlled through the foreman's own initiative.

HOUSEKEEPING

One of the most important factors of effective industrial hygiene and safety is housekeeping. There is little hope of success without it. Housekeeping requires the least investment, and brings great returns. The standard yard stick for measuring housekeeping is difficult. However, there are criteria of good housekeeping, which in themselves provide a rating system (Table 4).

TABLE 4 — GOOD HOUSEKEEPING RULES

1) Assign a place for every piece of equipment and material.
2) Place assigned should be determined by frequency of use. For example, seldom used patterns should be stored in an area remote from the working space.
3) Keep nothing in the work zone which is not necessary to operation.
4) At the end of the work period, tools, equipment and material should be stored as at the beginning.
5) If the plant is clean, each work zone should be in the same condition at the end of day as it was at the beginning.
6) Failure to keep production equipment in good repair equals bad operating. Failure to keep nonoperational equipment in good repair equals bad housekeeping. Hoods, lights, exhaust systems, ventilators, safety equipment should be kept in as good a condition as a piece of production equipment should be.
7) Besides daily cleanup — spring cleaning idea is also necessary.
8) Obsolete equipment, unusable material or equipment (and junk) should be disposed of.
9) Maintain well marked aisles, and keep them clear at all times.
10) Neglect of the physical plant is bad housekeeping (broken windows, damaged walls and floors, walks and stairways, leaky roofs. etc.).
11) Keep wash, locker and lunch rooms compatible with human dignity. Use this as a rating test — would you yourself use these facilities in this condition?
12) Neat piling of material is essential.

Here is an accident in which no one was injured. Tubs of sand had been piled five high. No attention was paid to the condition of the tubs. When the lift truck operator moved in to pick off the top one, the whole pile toppled over. Note in left hand corner, a valuable piece of equipment that was badly damaged. Also note the poor housekeeping.

Here is an accident that did not happen — but we will never know why. It is not posed. The picture was found in a desk drawer of a plant the author's company bought a few years ago. The only comment on the picture was "pouring alloy no. . . ." The mold is in a 20 ft pit. The pourer is on a small bottom board, on a nail keg, on a skid that has wheels at one end — and the skid is just inches from the edge of the pit.

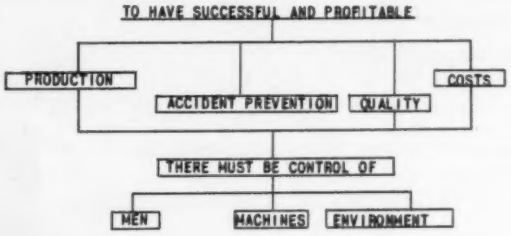
This is the company's President's Safety Trophy which is awarded to the plant which has the best all around safety performance for the year. This trophy has been awarded for seven years, and out of those seven years foundries have won won it five times.

WHY SUSTAINED EFFORT?

Why must the safety effort be repetitive and sustained?—Man is a peculiar animal when looked at en masse and objectively:

1) He will not look far beyond his own self interest.
2) He resents change and dislikes movement.
3) He usually forgets the past and remembers inaccurately.
4) He will not fight for things when he can find something to fight against.
5) He does not like to differ from the crowd unless certain his differences will be recognized as superior.
6) Except in periods of high emotion, he will not exert himself beyond the line of least resistance.
7) He will not act even in important matters unless properly followed up.
8) He resents being told what to do.

TABLE 5 — SUCCESS THROUGH CONTROL



CONCLUSION

An accident is a signal that something has been wrong in an operation. Unsafe conditions reveal the presence of a faulty design, equipment, arrangement, placement, training or operating procedure.

Your cooperation in making design, equipment, arrangement, placement, training and procedure as perfect as possible will eliminate as nearly as humanly possible all causes of accidents.

The elimination of all causes is the aim.

The life line of accident prevention is anticipation.

AUSTENITIC MANGANESE STEELS

Some metallurgical factors influence

by T. E. Norman, D. V. Doane and A. Solomon

ABSTRACT

The results of studies leading to the improvement of wear resistance and mechanical properties of cast austenitic manganese steels is presented. Modifications in composition and heat treatment were studied. The development of improved abrasion resistance in cast 12 per cent manganese austenitic steel while retaining the high ductility characteristic of this type of steel, and the development of lean alloy austenitic steels which combine moderate ductility with markedly improved abrasion resistance are outlined.

INTRODUCTION

In the operations of the authors' company's mine and mill at Climax, Colo., steels having the characteristically high toughness of austenitic 12 per cent manganese steels are required in a number of major wearing parts. Some of these are in the slusher scrapers in the underground operations and in the gyratory and cone crusher liners in the crushing plant. In other major wearing parts, such as grinding mill liners, more wear resistant and less ductile types of ferrous alloys are used, such as those discussed in previous papers by the authors.[1,2,3]

Austenitic types of high carbon steel, such as the classic Hadfield manganese steel, have a combination of desirable properties, both for processing and use, which make them commercially attractive. If these properties could be combined with improvements in resistance to wear and flow in service, then it is obvious that these austenitic steels would become more securely entrenched in those applications where high toughness is required. At the same time, they would probably regain some of the markets they have lost in those applications where high toughness is a desirable but not absolutely necessary requirement in wearing or structural parts.

Part of a continuing investigation into means for improving the wearing qualities, and in some cases the mechanical properties, of high carbon austenitic steels are covered in this report. Preliminary studies indicated two promising lines of attack on the problem. In one, the use of special alloy additions to 12 per cent manganese steel were combined with modifications of the conventional heat treatment to provide improvements in both wear resistance and strength, with little or no loss in ductility.

With this line of attack, improved austenitic steels suitable for use in slusher scrapers, in cone crusher liners and in other parts requiring high ductility have been developed. This development is covered in the first part of the paper.

The second line of attack was an exploration of lower alloy contents in high carbon austenitic steels to achieve improved wear resistance at a somewhat lower ductility or toughness level. "Lean alloy" austenites gave promise of fulfilling these requirements, particularly under conditions of high stress abrasion.[2] The development and study of these lean alloy austenitic steels has now been carried to the point where a commercially suitable alloy has been developed for use in parts requiring only moderate ductility or strength, combined with a high degree of abrasion resistance.

Such parts include grinding mill liners, grinding mill scoop lips, screen decks and possibly jaw crusher liners. This development is covered in the second part of the paper.

DEVELOPMENT OF STEELS WITH IMPROVED WEAR RESISTANCE AND HIGH TOUGHNESS

To improve the wear resistance of austenitic manganese steels without, at the same time, seriously injuring their toughness, a logical approach appeared to lie in the production of properly dispersed hard carbides in the austenitic matrix of the steel. Increasing the carbon in solution in the austenite was also a possible approach. It has been observed, however, that in the conventional Hadfield manganese steel, an increase in the carbides, or the carbon in solution, was usually accompanied by the formation of embrittling-type carbide envelopes around grain boundaries or as plates along crystallographic planes.

To avoid such embrittlement, the form in which the carbides occurred in the austenite would obviously have to be modified, either by addition of other alloying elements or by special thermal treatments. Both

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possibilities have been investigated, and the results to date are summarized in the report.

COMPOSITION MODIFICATIONS EFFECT

Carbon

Many investigators have reported the influence of carbon on the properties of austenitic manganese steel. In combination with manganese, it greatly influences the characteristics of the austenite, including such properties as tensile and yield strength, ductility, stability and wear resistance.

In general, for wear resistant castings, it is desirable to hold the carbon content at the highest level possible without seriously injuring the ductility of the steel. For the conventional Hadfield steel, this is usually in a range of 1.10 to 1.25 per cent. Higher carbon contents than 1.25 per cent usually tend to embrittle the steel by forming envelopes of $(Fe,Mn)_3C$ type carbides around the grain boundaries, or by forming plate-type carbide precipitates along crystallographic planes. Means of avoiding this embrittlement, by modification of the type of carbide, will be discussed in subsequent sections.

Manganese

To retain a fully austenitic structure, the manganese content of an austenitized and quenched high carbon steel must be above certain minimum levels. Figure 1 indicates these levels for steels with varying manganese and carbon contents, as have been determined by several investigators.[4,5,6,7]

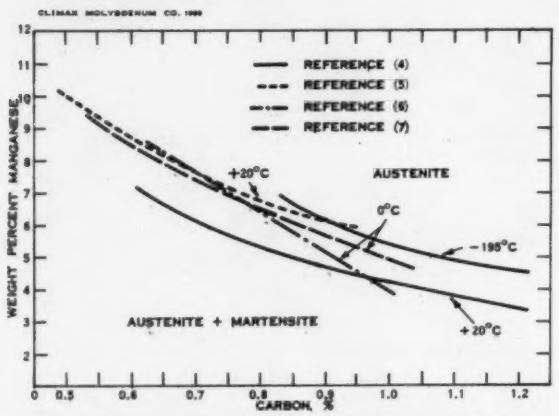

Fig. 1 — Comparison of Ms temperatures measured by various investigators.

The data in Fig. 1 indicate that a quenched steel containing, for example, 1.20 per cent carbon, will be fully austenitic when it contains 5 to 6 per cent manganese. The development of high ductility and toughness in the austenite generally requires in excess of 10 per cent manganese. This is illustrated in Fig. 2, which summarizes tensile properties obtained by the authors on a number of austenitized and quenched 1.2 per cent carbon steels with from 5.5 to 13 per cent manganese.

Commercially produced austenitic manganese steel

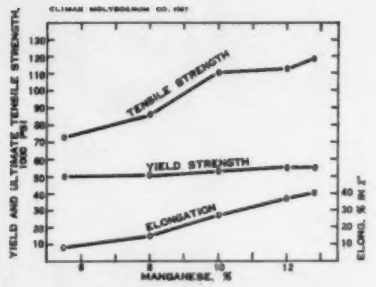

Fig. 2 — Manganese content effect on tensile properties of cast austenitic steel water quenched from 1800 F - 1900 F (after pearlitizing at 1100 F). 1.14 - 1.20 per cent C, 0.61 - 0.69 per cent Si, 0.045 - 0.058 per cent P.

castings generally contain 11 to 14 per cent manganese, with a manganese-carbon ratio of about 10 to 1 or higher. The necessity of adhering to specific manganese-carbon ratios in formulating compositions is, however, questioned by the authors.

Chromium, Nickel, Molybdenum

Influence on As-Cast Properties. Heavy section castings made from the higher carbon grades of austenitic manganese steel are often prone to cracking in the foundry while they cool in their as-cast condition. This is believed to be due largely to embrittlement resulting from precipitation of carbides around grain boundaries or as plates along crystallographic planes. It is well-known that chromium additions tend to aggravate this condition, and this is confirmed by the authors' observations. Molybdenum, on the other hand, when present in amounts over about 1.5 per cent, produces a globular type of carbide which forms from the melt in interdendritic sites and minimizes the development of grain boundary Fe_3C type carbides.

This is illustrated in Fig. 3, which compares the as-cast microstructures, sand cast in 2-in. thick sections, of plain 1.2 per cent carbon-manganese steel with the microstructures of two 2 per cent molybdenum steels containing 1.2 and 1.7 per cent carbon.

The globular type of carbide formed in as-cast structures of the 2 per cent molybdenum steels has also been observed in heavy sections such as 10-in. diameter risers used on large castings. It persists with carbon contents up to about 1.7 per cent and is believed to be an M_6C type complex carbide. The carbide formed in the plain or chromium modified manganese steels are of the $(Fe,Mn)_3C$ type. The globular type of carbide formed in the as-cast 2 per cent molybdenum steels should permit the use of higher carbon contents, possibly up to as high as 1.7 per cent in commercial castings.

Influence on Solution Treated Properties. The effects of the three most commonly used alloying elements – chromium, nickel and molybdenum – on the mechanical properties of light section castings are summarized by Avery and Chapin[8] in Fig. 4. This indicates that molybdenum additions up to about 2 per cent increases the yield strength without lowering the ductility or tensile strength. Chromium increases the yield strength, although at a slower rate, but

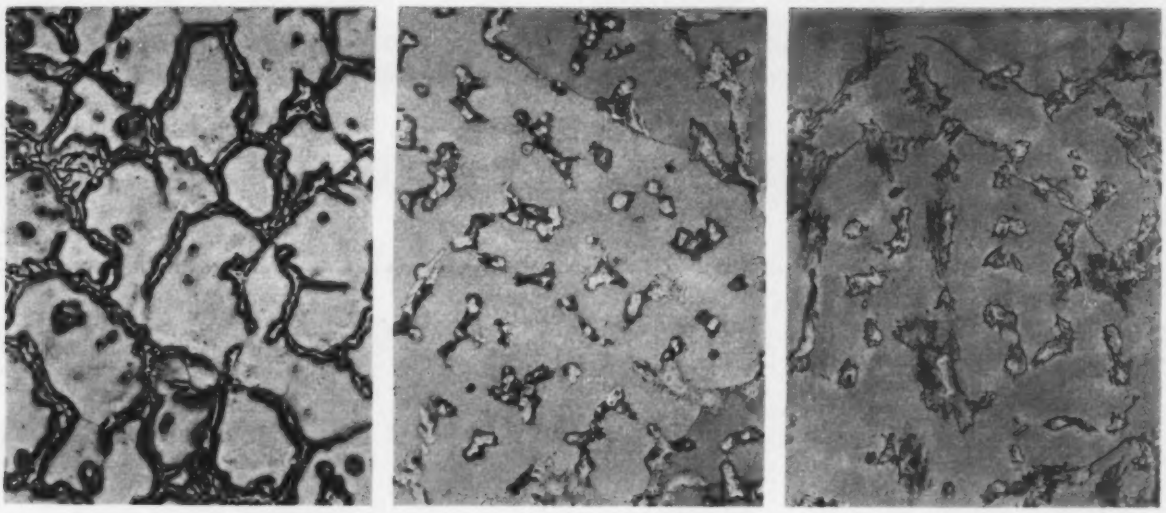

Fig. 3 — Molybdenum and carbon influence on as-cast microstructures of 12 per cent manganese steels. *Left* — 1.34 per cent C, 12.85 per cent Mn; center — 1.30 per cent C, 12.31 per cent Mn, 2.0 per cent Mo; *right* — 1.7 per cent C, 12.0 per cent Mn, 2.0 per cent Mo. 2 per cent nital etch. 100 ×.

lowers the ductility and tensile strength. Nickel does not show a strengthening effect.

Additions of chromium, which tend to accentuate the formation of carbide networks around grain boundaries, are probably responsible for the reduced ductility of austenitic manganese steels containing over about 1 per cent chromium. A comparison of the tensile properties obtained by the authors from two high carbon austenitic manganese steels in Table 1 further confirms the embrittling effect of a 3 per cent chromium addition in light section castings. The chromium addition does, however, improve yield strength, and presumably would improve resistance to flow in service.

In spite of the embrittling effect of chromium, an addition of about 2 per cent is frequently used in the belief that it improves resistance to wear in service. The authors' observations indicate that under some conditions, chromium additions do improve wear resistance, although similar or greater improvements may be obtained by lowering the manganese content of a chromium-free steel, with less loss in ductility. These effects will be covered more fully in the second part of this paper.

TABLE 1 — CHROMIUM INFLUENCE ON HIGH CARBON AUSTENITIC MANGANESE STEEL MECHANICAL PROPERTIES

(Water Quenched from 2000 F)	Heat 3433	Heat 3436
C, %	1.34	1.34
Mn, %	12.0	12.0
Mo, %	0.5	0.5
Cr, %	0	3.0
0.2% Offset Yield Strength, psi	59,900	68,400
Ultimate Tensile Strength, psi	105,400	106,900
Elongation, %	26.0	18.0
Reduction in Area, %	31.5	16.0
Brinell Hardness	207	228

Silicon

Silicon is normally added only in the amounts required for good deoxidation of austenitic manganese steel heats. However, Avery[9] has reported that it may be added in amounts up to about 2 per cent to pro-

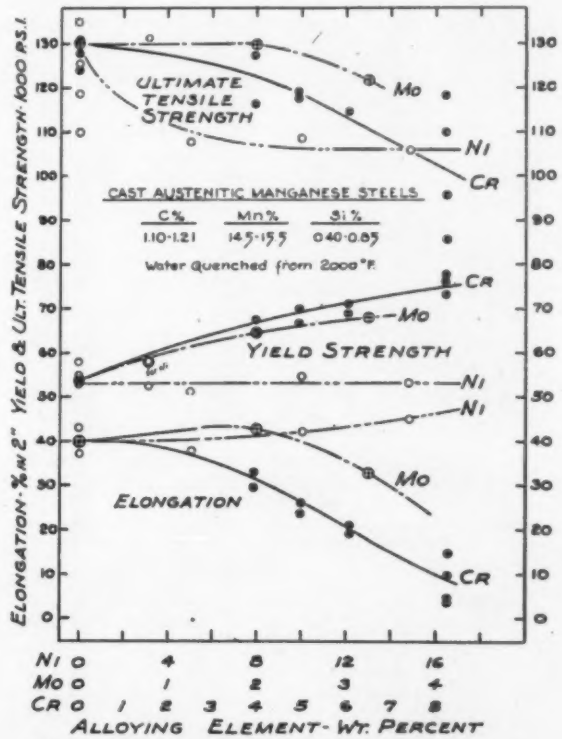

Fig. 4 — Nickel, molybdenum and chromium effect on tensile properties of cast austenitic manganese steel. Cast as one in. diameter test bars, reheated and water quenched from 2000 F (reference 8).

duce a moderate improvement in yield strength.

The authors' investigations on both 12 and 6 per cent manganese austenitic steels with increasing silicon contents up to 2 per cent confirm Avery's data. It was also noted that the higher silicon contents tended to throw carbon out of solution in the austenite by precipitating the carbon either as rather massive carbides or as pearlite. This effect of silicon was observed both in as-cast steels and in the same steels after various thermal treatments. This apparent incompatibility of carbon and silicon in solution in the austenite has also been observed in other high carbon types of steel and in the white irons.

Presumably, where a high carbon content in solution in austenite is required for good wear resistance, the effect of higher than normal silicon contents would be harmful. This has been confirmed by the authors' wear tests, and by service results on ball mill liners reported by Mussgnug.[10]

Phosphorus

Because of its generally harmful effect on the mechanical properties of austenitic manganese steel, it is necessary to consider phosphorus as one of the important variables in composition. Phosphorus is probably particularly harmful in heavy section castings, due to segregation effects.

The A.S.T.M. Specification A128-33 for manganese steel castings limits phosphorus to a maximum of 0.10 per cent. Avery[9] has reported that above about 0.10 per cent phosphorus, the room temperature ductility and tensile strength drop off rapidly. These results were probably from tensile bars cut from light section castings. Also, Avery's work indicated that over 0.06 per cent phosphorus reduces hot strength and ductility which may result in hot tears in the castings. Weld deposits of austenitic manganese steels appear to be particularly sensitive to phosphorus contents over about 0.02 per cent, as reported by Avery and Chapin[8] and by DeLong, Lutes and Reid.[11]

The authors' investigations on manganese-molybdenum austenitic steels cast in 2 in. thick keel block sections indicate that castings containing 0.077 to 0.080 per cent phosphorus had definitely inferior tensile properties to those having similar compositions and treatments with 0.05 per cent or less phosphorus. This is illustrated by data in Table 2. Consequently, a phosphorus content of not over 0.06 per cent, and preferably under 0.05 per cent, is now specified on all of the austenitic steel castings used in the mining and milling operations at the authors' company.

TABLE 2 — PHOSPHORUS INFLUENCE ON AUSTENITIC MANGANESE STEEL MECHANICAL PROPERTIES

(Dispersion Hardened by Pearlitizing at 1100 F and Austenitizing at 1800 F)

	Heat 3522	Heat 3450
Carbon, %	1.22	1.22
Manganese, %	11.9	10.9
Silicon, %	0.51	0.60
Molybdenum, %	2.0	2.0
Phosphorus, %	0.019	0.077
Yield Strength, psi	65,000	64,000
Ultimate Tensile Strength, psi	117,500	95,600
Elongation, %	29.2	18.0
Reduction in Area, %	28.0	22.0
Brinell Hardness	217	228

THERMAL TREATMENT MODIFICATION EFFECT

Dispersion Hardening Heat Treatment Development

The desired objective of producing fine carbide dispersions in the regular Hadfield type or specially alloyed austenitic manganese steels does not appear to be feasible with the conventional solution treatment, which involves heating to 1900-2000 F, followed by a water quench. However, a consideration of the phase diagrams for high carbon steels containing in excess of 1.5 per cent molybdenum indicated that there should be a good possibility of producing the desired carbide dispersions in austenitic manganese steels by combining a 2 per cent molybdenum addition with modifications in thermal treatment. It appeared probable that if such an objective could be attained, improvements in both wear resistance and mechanical properties would be obtained.

In an investigation of these possibilities, it was determined that fine carbide dispersions could be produced and retained in 2 per cent molybdenum austenitic manganese steels by a special heat treatment which involved first a transformation of part of the austenite to pearlite, followed by a temperature controlled re-austenitizing treatment. This dissolved most of the globular carbides and part of the carbides in the pearlite, so the remainder of the carbides formed a fine dispersion of spheroidized carbides in the austenite.

To produce pearlite in austenitic manganese steel, it was found that an isothermal subcritical anneal at 1100 F was most effective. In a 12 to 14 per cent manganese composition, it was found that the austenite to pearlite reaction would proceed fairly rapidly during the first few hours at 1100 F, and would then slow down to an apparent equilibrium condition after about 12 hr, leaving about 35 to 50 per cent of the austenite untransformed.

The controlled re-austenitizing treatment which follows the pearlitizing treatment has been done at temperatures ranging from 1600-1900 F. As would be expected, an austenitizing temperature of 1600 F leaves greater amounts of spheroidized carbides in the structure than an austenitizing temperature of 1900 F.

Microstructure Comparison

Figure 5 shows typical microstructures produced by the various austenitizing temperatures, and also shows for comparison the pearlitized structures of the same steels. It may be seen from a comparison of these structures that the fine carbide dispersion in the final structures exists principally in the areas which were pearlitic after the 1100 F treatment. In addition to producing the carbide dispersion, the pearlitized areas also produce a grain refinement in the final structure. It is believed that this grain refinement plays an important part in controlling the

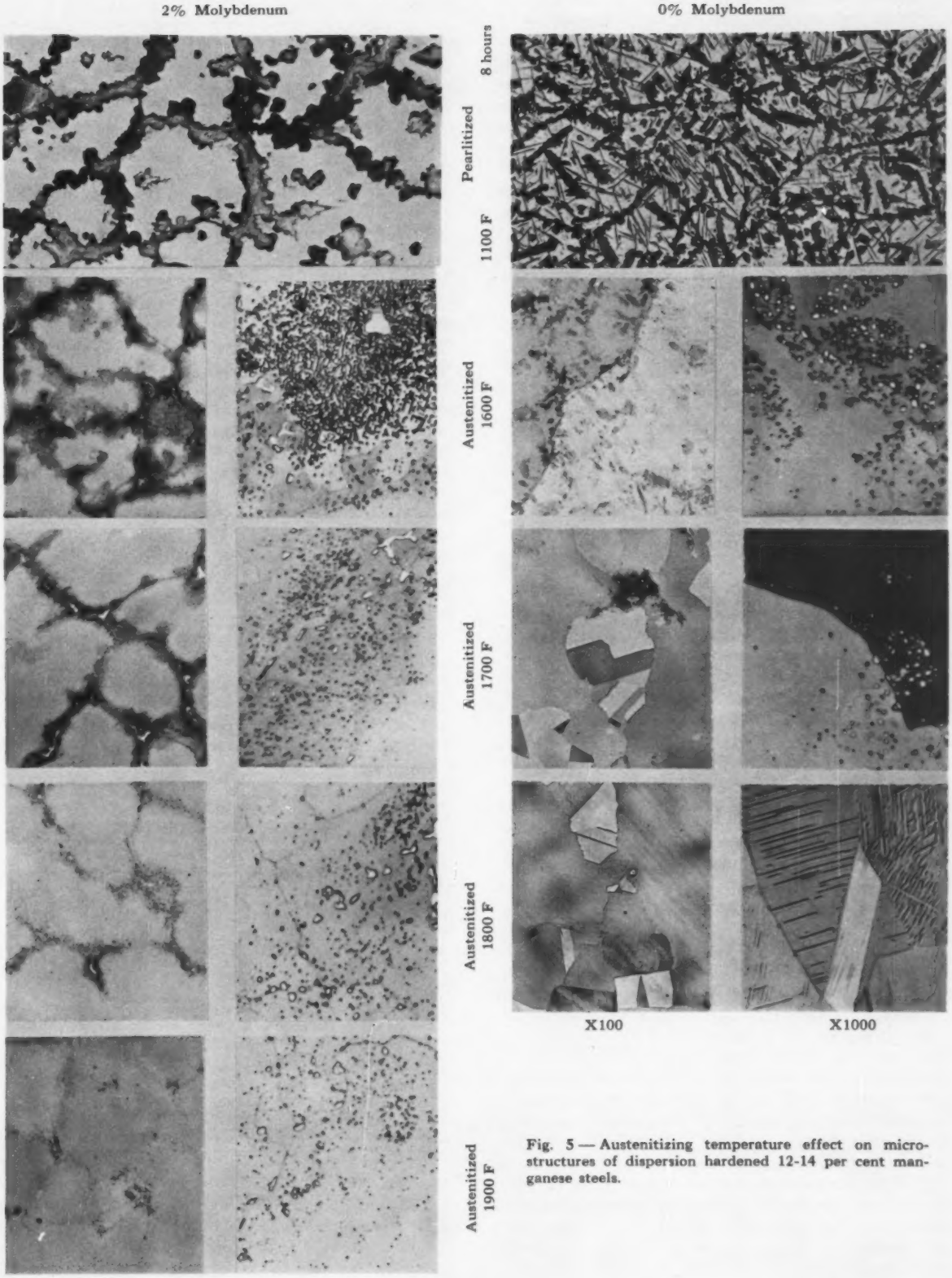

Fig. 5 — Austenitizing temperature effect on microstructures of dispersion hardened 12-14 per cent manganese steels.

ductility and possibly the tensile strength of the final, "dispersion hardened" structures.

Figure 6 gives typical mechanical properties of 1.1 to 1.2 per cent carbon, dispersion hardened compositions with properties corresponding to the structures in Fig. 5. The 1600 F austenitizing temperature produces the highest yield strength of the series, but also produces the lowest elongation. Consequently, it is believed that the 1600 F treatment would be suitable only for castings used in relatively low impact service. With the higher austenitizing temperatures of 1700 to 1900 F, the ductility is greatly improved with some lowering in yield strength.

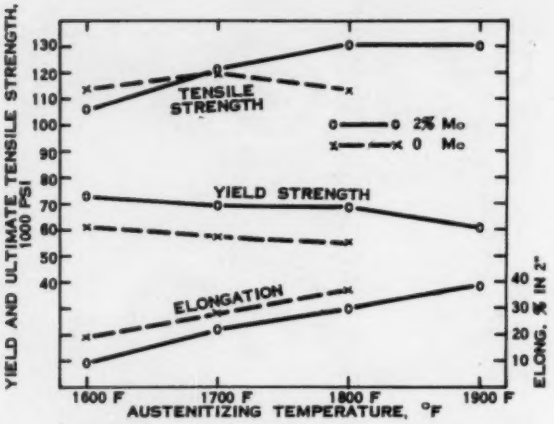

Fig. 6 — Austenitizing temperature effect on tensile properties of austenitic steel (after pearlitizing at 1100 F). 1.1 - 1.2 per cent C, 12.0 - 14.0 per cent Mn.

Since the 1900 F treatment dissolves most of the carbide dispersion, it was felt that the best compromise austenitizing temperature for heavy duty castings, such as crusher liners, would be in a range of 1700 to 1800 F. For the dispersion hardened cone crusher liners and slusher scrapers used in the authors' company's operations, an austenitizing temperature of 1800 F has been used on practically all of the castings worn out to date.

Molybdenum Influence on Dispersion Hardening

The possibility that plain 12 per cent manganese steel compositions might respond to the dispersion hardening treatment has been investigated. The microstructures in Fig. 5 indicate that the plain manganese steel will develop some carbide dispersion when re-austenitized at 1600 F, but this is almost completely dissolved when the re-austenitizing temperature is raised to 1700 F or higher. The dispersion hardening treatment appears, therefore, to be relatively ineffective in the plain manganese steel.

This is further confirmed by the data in Table 3, in which is presented a comparison between the plain and 2 per cent molybdenum-manganese steels both in the conventionally treated and dispersion hardened conditions.

The effects of molybdenum and dispersion hardening on heavy section castings are indicated by the

TABLE 3 — PROPERTIES OF 2 IN. KEEL BLOCK SECTIONS

	Yield Str., psi	Tensile Str., psi	Elong., % in 2 in.	Red. of Area, %	Brinell Hardness
Regular Manganese Steel					
1900 F, Water Quenched	55,000	115,000	40	30	175
1100 F + 1800 F, Water Quenched	55,000	113,000	35	35	175
12-2 Alloy					
2000 F, Water Quenched (from Avery*)	64,000	130,000	42	—	—
1100 F + 1800 F, Water Quenched	69,000	130,000	30	25	212

*Reference 8, cast 1 in. test bars.

data in Table 4, which shows the tensile properties and hardness values of specimens cut from 6,000-lb cone crusher mantles which had sections originally about 4 in. thick. In these heavy sections, the 2 per cent molybdenum steels, in addition to having higher yield and tensile strengths, also exhibit better ductility than the plain manganese steels. Service results on these liners at the authors' company provide confirmation of the greater ductility of the 2 per cent molybdenum steels, since they have shown less tendency to premature failure by cracking than the plain manganese steel liners.

Manganese Influence in Dispersion Hardened Austenite

Manganese contents of less than 12 to 14 per cent were investigated for dispersion hardened 1.2 per cent carbon compositions, with and without 2 per cent molybdenum. This was investigated since it was indicated that lower manganese contents would permit a greater degree of pearlitization during the 1100 F holding

TABLE 4 — PROPERTIES OF SPECIMENS CUT FROM WORN CRUSHER MANTLES

	0.2% Offset Yield Str., psi	Tensile Str., psi	Elong., %	Red. in Area, %	Brinell Hardness
Regular Manganese Steel					
1900 F, Water Quenched	59,000	68,400	6.5	9.3	187
	60,500	76,400	8.5	11.3	187
12-2 Alloy					
2000 F, Water Quenched	65,500	88,900	14.0	18.6	197
	66,600	91,500	15.5	27.2	217
1100 F + 1800 F, Water Quenched	64,500	108,000	22.5	21.2	217
	69,700	123,100	25.0	22.2	223
	—	119,400	26.0	22.4	223
	69,500	100,700	15.0	14.7	217

period and, this in turn, would permit the development of a more complete or uniform dispersion of carbides, together with more grain refinement when the steels were re-austenitized and quenched from 1600-1800 F. There was also the possibility that the lower manganese contents would provide better wear re-

sistance due partly to the better carbide dispersion and partly to the less stable austenite in the lower manganese steels.

The average tensile properties and hardness values obtained from this investigation are given in Table 5. The expected increase in carbide dispersion with the lower manganese contents was obtained. The structures were accompanied, however, by lower mechanical properties and toughness. In the interests of obtaining improved wear resistance, the lower manganese steels with their lower toughness should be usable in many applications. However, for large cone crusher liners, experience has indicated that a high degree of toughness is necessary to avoid premature failure by breaking or cracking. Consequently, none of the lower manganese steels have yet been tried in cone crusher liners at the authors' company.

Carbon Influence in Dispersion Hardened Austenite

Increasing carbon content is generally one of the most effective means of improving wear resistance. In the straight 12 per cent manganese steel, increasing carbon effectively improves yield strength and presumably improves wear resistance. However, carbon levels over about 1.25 per cent may cause trouble in heat treatment or foundry handling,[9] and may even lead to erratic service life; consequently, the carbon content is normally limited to about 1.20 per cent. The favorable influence of molybdenum in suppressing continuous grain boundary carbides indicated the possibility of using higher carbon contents without encountering this brittleness.

In the heat treatment of the 12 per cent manganese-2 per cent molybdenum dispersion hardened steels, it was found that increasing carbon contents increased the amount of pearlite produced during the 1100 F pearlitizing treatment. This, in turn, produced more grain refinement when the steels were re-austenitized and quenched. It is believed that this grain refinement is largely responsible for the superior tensile strengths and ductilities, shown in Table 6, for the pearlitized and re-austenitized steels when compared to the same compositions in their as-cast and re-austenitized condition. In addition, the influence of carbon in increasing yield strength and hardness is evident from the data in Table 6.

TABLE 5 — MANGANESE INFLUENCE ON DISPERSION HARDENED AUSTENITE MECHANICAL PROPERTIES

C, %	Mn, %	Mo, %	Austenitizing Treatment, F	0.2% Offset Yield Str., psi	Tensile Str., psi	Elong., %	Red. in Area, %	Bhn, Av. (3000 kg)
1.14	8.3	—	1600	54,600	84,100	7.8	10.6	202
			1700	50,600	89,850	16.5	19.6	187
			1800	51,000	86,600	15.0	17.7	187
1.16	8.1	2.1	1600	72,900	119,400	8.5	11.5	277
			1700	63,550	112,300	15.0	17.0	241
			1800	59,350	94,850	12.2	18.6	223
1.19	10.1	—	1600	57,600	94,600	11.0	17.6	210
			1700	55,700	117,000	27.0	30.2	187
			1800	54,050	110,500	27.5	34.8	183
1.19	10.0	2.2	1600	69,550	110,700	12.8	14.4	241
			1700	68,550	123,400	21.5	22.8	228
			1800	63,900	113,350	22.5	24.4	206
1.19	12.0	—	1600	61,200	113,650	19.5	20.5	206
			1700	57,600	119,950	28.0	27.8	170
			1800	55,150	113,250	37.2	34.3	170
1.20	11.6	2.0	1600	72,850	106,100	9.8	10.4	241
			1700	69,400	121,850	22.0	21.1	212
			1800	68,850	130,450	30.0	25.8	206

All values represent average of duplicate tests. Specimens were solution treated at 1900 F (2 hr) and water quenched; then pearlitized at 1100 F prior to the austenitizing treatment shown. The specimens were water quenched after the final austenitizing treatment.

TABLE 6 — INCREASING CARBON AND DISPERSION HARDENING EFFECT ON AUSTENITIC MANGANESE-MOLYBDENUM STEEL MECHANICAL PROPERTIES

C, %	Mn, %	Si, %	Mo, %	Thermal Treatment, F	0.2% Offset Yield Str., psi	Tensile Str., psi	Elong., %	Red. in Area, %	Bhn
Carbon Series									
1.22	11.9	0.5	2.0	P + 1800	65,050	117,500	29.2	28.0	217
				P + 1900	63,150	109,500	31.2	31.8	223
				AC + 1800	61,900	83,850	14.8	24.7	223
1.32	11.9	0.6	2.1	P + 1800	69,000	131,900	32.0	31.4	228
				P + 1900	68,550	116,900	32.0	33.2	228
				AC + 1800	66,500	109,250	26.5	25.2	241
1.47	12.0	0.5	2.0	P + 1800	72,150	125,700	27.0	24.7	241
				P + 1900	69,700	118,550	30.0	28.2	228
				AC + 1800	69,550	99,300	15.8	17.2	235
Silicon Series									
1.23	12.3	0.9	2.1	P + 1800	69,400	118,900	22.8	22.4	228
				P + 1900	66,800	113,100	30.5	27.5	228
				AC + 1800	64,250	96,800	21.2	24.6	228
1.28	11.8	1.5	2.0	P + 1800	71,500	125,800	27.5	24.5	241
				P + 1900	65,750	107,750	25.0	26.3	241
				AC + 1800	65,450	92,300	15.0	19.6	228

Values represent average of duplicate tests. P indicates that samples were pearlitized by holding at 1100 F for 12 hr and air cooling to room temperature prior to austenitizing treatment indicated. AC indicates that samples were in the as-cast condition prior to austenitizing. All samples were water quenched from austenitizing temperature after holding one hr at temperature.

The strength, hardness and ductility of the higher carbon 12-2 alloys, together with the possibilities for improved wear resistance, were sufficiently good to justify their consideration for cone crusher liners at the authors' company. Consequently, several liners with carbon contents of 1.4 to 1.5 per cent have been purchased and are now in service. It is worth while to note that no difficulties were experienced in production to these liners at the foundry.

The higher carbon compositions have combinations of yield strength and ductility which may also make them attractive for heavy duty castings in structural applications, such as in logging or anchor chain.

Silicon Influence

Table 6 shows the influence of increasing silicon on the mechanical properties of the 12 per cent manganese-2 per cent molybdenum austenitic steels. A mild increase in yield strength and hardness, with probably some loss in ductility, is indicated. The microstructures of these higher silicon steels, in both the as-cast and dispersion hardened condition, indicate that increasing silicon contents tend to increase the quantity of undissolved carbides in the structures. These carbides were relatively coarse, and were distributed principally at the grain boundaries. From observations of both mechanical properties and struc-

ture, there appeared to be little advantage, and possibly some disadvantage, from the use of higher than normal silicon contents.

RESISTANCE TO WEAR

Gouging Abrasion

Hadfield manganese steel is best suited for applications involving heavy impact and gouging abrasion. Several years of experience have proved that the 12 per cent manganese-2 per cent molybdenum modification gives best performance under similar conditions. Solution treated 12 per cent manganese-2 per cent molybdenum steel usually shows some benefits over Hadfield manganese steel and the 2 per cent chromium type, particularly where large sections or heavy impact is involved.

For instance, in cone crusher liners at the authors' company, conventionally treated 12 per cent manganese-2 per cent molybdenum steel had a normal service life only slightly above that of the straight 12 per cent manganese steel. However, the 2 per cent molybdenum mantles were less susceptible to cracking and consequent premature failure when worn thin. Also, the 2 per cent molybdenum bowl liners showed no cracking around supporting hooks, a frequent characteristic of plain manganese bowl liners in the same equipment.

In certain cases, the 12 per cent manganese-2 per cent molybdenum steel has also been advantageous where straight wear resistance is the key factor, as in the case of a crusher for roofing granules where the 2 per cent chromium type gave a life of 484 to 505 hr, as compared to 665 hr for the 2 per cent molybdenum steel with a conventional treatment. The most significant improvement, however, has come when the 12 per cent manganese-2 per cent molybdenum steel has been dispersion hardened. Conclusive evidence of the superiority of the 12-2 alloy, dispersion hardened, is given in Fig. 7, by frequency charts of the life obtained on cone crusher liners at the authors' company.

The 12 per cent manganese-2 per cent molybdenum composition has been used in a number of other applications, including hammers for impact pulverizers, stationary jaw crushers, grizzly screen sections and blades on folding-type scrapers. On the whole, the dispersion hardened 12 per cent manganese-2 per cent molybdenum steel has demonstrated a longer life than Hadfield manganese steel – ranging up to 40 per cent better – and greater resistance to flow. In isolated cases, as that of a slag-crushing unit, more spectacular improvements in life, up to three times longer than that of the straight manganese steel, have been reported.

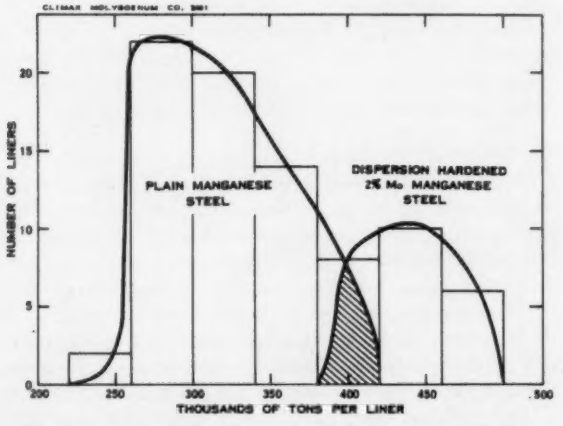

Fig. 7 — Frequency chart of service life of standard cone crusher liners at authors' company between 1955 - 1959.

High Stress Abrasion

In conditions involving high stress abrasion,[2] such as in grinding mill liners, best wear resistance has been obtained when the carbon in steel compositions was kept in solution, rather than having it present as carbides in the structures. It was not surprising, therefore, to find that the solution treated 12 per cent manganese, or 12 per cent manganese-2 per cent molybdenum austenitic steels had better wear resistance in ball mill service at the authors' company than the same compositions in the dispersion hardened condition. The loss in wear resistance, as a result of the dispersion hardening treatment amounted to about 5 per cent when comparisons were made by the wear test procedure.[2]

The wear test results for the 12 per cent manganese steels in grinding mill service at the authors' company are of academic interest only, since the relatively high wear rates on all of these steels makes them economically unsuited for ball mill liner service in the mills.

DEVELOPMENT OF STEELS WITH IMPROVED WEAR RESISTANCE AND MODERATE TOUGHNESS

Some abrasion resistant parts requiring moderate toughness, such as certain grinding mill liners, ball mill scoop lips, screen bars, discharge grates, roll shells, impact pulverizer liners and hammers, slurry pipe and certain earthmoving parts, need better abrasion resistance than that of Hadfield manganese steel, yet the full ductility and toughness of this steel is not necessary. While certain of the martensitic steels have good wear resistance, they may present serious foundry and heat treatment problems when heavy sections or complicated shapes are involved.

In these cases, high residual stresses may be set up that, because of the high yield strength and relatively low ductility, cannot be relieved at the low tempering temperatures that must be used for good wear resistance. On the other hand, an austenitic alloy would not present these difficulties, and residual stresses would be comparatively low in view of the low yield strength. This explains the interest in an austenitic material combining moderate ductility with good abrasion resistance.

A possible clue to suitable austenitic compositions which would have good wear resistance was provided by wear tests on grinding balls, using a test procedure developed at the authors' company,[1,2] and by further wear tests on materials for grinding mill liners.[2] In all of these tests it was noted that when high car-

TABLE 7 — RESULTS FROM PRELIMINARY SERIES OF LEAN ALLOY AUSTENITIC STEELS[1]

Item No.	Composition, % C	Mn	Cr	Mo	Ni	Cu	Micro-structure[2]	Hardness, Bhn	0.2% Yield Str, psi	Tensile Str, psi	Elonga-tion, %	Reduction of Area, %	Abrasion Factor[3]
1	1.34	12.0	—	0.5	—	—	A	207	59,900	105,400	26.0	31.5	136
2	1.37	6.0	—	0.5	—	—	A	217	56,800	83,700	15.0	23.1	114
3	1.34	3.0	—	0.5	—	—	A	201	Y-block cracked on quenching				broke
4	1.34	12.0	3.0	0.5	—	—	A,C	228	68,400	106,900	18.0	16.0	128
5	1.35	5.9	3.0	0.5	—	—	A,C	228	66,100	87,500	10.0	10.0	broke
6	1.33	3.0	3.1	0.5	—	—	A,C,Dgb	241	67,100	82,600	4.5	5.9	broke
7	1.36	1.5	3.0	0.5	—	—	A,C,Dgb	248	Y-block cracked on quenching				broke
8	1.34	1.5	3.1	0.5	10.0	—	A,C	241	58,700	84,000	9.5	11.3	127
9	1.34	1.5	3.0	0.5	5.1	—	A,C	228	59,900	67,800	4.0	5.0	broke
10	1.34	1.5	3.0	0.5	2.6	—	A,C	207	59,900	72,300	3.0	5.5	broke
11	1.33	1.5	3.0	0.5	—	3.0	A,C,Dgb	228	63,000	72,700	2.5	3.7	broke
12	1.35	2.4	3.0	0.5	—	3.0	A,C	241	58,300	72,700	5.0	11.3	broke
13	1.35	2.4	—	0.5	—	6.3	A,Dgb	223	56,800	70,400	5.0	9.1	broke
14	1.36	1.5	3.0	0.5	—	6.2	A,C,Dgb	255	62,000	75,800	3.5	2.8	broke
15	1.35	1.5	3.0	1.0	—	—	A,C	235	Y-block cracked on quenching				broke
16	1.33	1.5	3.0	2.0	—	—	A,C	241	Y-block cracked on quenching				broke

1) All groups solution treated by a water quench from 2000 F.
2) Microstructures observed:
A — Austenite
C — Carbide phase
Dgb — Dark-etching grain boundaries (probably carbide envelopes)
3) Abrasion factor is rate of wear relative to a factor of 100 for a 1.0% carbon, 0.8% manganese, 6.1% chromium, 1.0% molybdenum martensitic steel air quenched from 1900 F.

bon low alloy steels had structures which were partially, or in some cases fully austenitic, they had outstanding abrasion resistance which, in many instances, was even better than that of the martensitic steels and martensitic white irons.

With the fact well-established that lean alloy, high carbon austenitic steels were capable of providing good wear resistance, the next task was to develop compositions of this type which would also have adequate toughness for commercial use in a wide variety of wearing parts. It was further indicated by the prior tests[2] that to have adequate toughness, the austenitic steels should have *Ms* temperatures well below normal room or atmospheric temperatures, to prevent transformation and resultant embrittlement in service. The desired objectives could best be attained by confining the investigation to those high carbon lean alloy steel compositions which were capable of retaining fully austenitic structures under all conditions of service.

COMPOSITIONS INVESTIGATED

For a preliminary evaluation, a rather broad range of austenitic compositions was investigated. A molybdenum addition of 0.5 per cent or more was made to each of these to assist in suppressing pearlite and embrittling types of carbides in their structure. Each composition was sand cast and heat treated both as Y-blocks for tensile test specimens and as 4½-in. diameter balls which were tested in a 9 ft diameter primary ball mill at the authors' company in "wear-in" and wear tests according to the procedure outlined in a reference.[2] Table 7 lists the compositions, microstructures, hardness, tensile properties and abrasion factors (relative wear rates) obtained from this series.

The Y-blocks from all of the compositions in Table 7 appeared to have a fully austenitic matrix, as was indicated by their microstructure, hardness and magnetic tests. In spite of this, only items 1, 2 and 8 exhibited satisfactory toughness in the 4½-in. diameter balls tested. The 12 per cent manganese-3 per cent chromium steel (item 4, Table 7) also survived both the wear-in and wear test. However, circumferential cracks developed in the balls of this group so that they probably would have broken after further service. The breakage on the remaining groups occurred mainly during the 172-hr wear-in period, and only groups 1, 2, 4 and 8 survived through the subsequent 150-hr wear test.

It was concluded, from the observed microstructures and the results in Table 7, that the 3 per cent chromium addition, with its resultant production of undissolved and grain boundary carbides in the austenite, was largely responsible for the breakage which occurred on the test balls in this series. Some of the compositions, such as items 3, 7, 15 and 16, also probably had an insufficient amount of austenite stabilizing elements to retain a fully austenitic structure in zones of alloy segregation, such as can exist near the center of the balls. Magnetic tests on the recovered sections from the broken balls indicated the presence of non-austenitic phases near the center of many of the broken balls.

The good abrasion factor and relatively good ductility and toughness of item 2 suggested that a simple composition, dependent only on a suitable balance of carbon, manganese and molybdenum, could be used to produce a commercially useful lean alloy austenitic type of steel. It appeared that the carbon content should be near the maximum amount which could be held in solution, the manganese should be

near the minimum permissible for full retention of austenite and sufficient amounts of molybdenum should be used to suppress the formation of embrittling-type carbides and/or pearlite, particularly in heavy section castings.

Carbon and Manganese Content

Figure 1 suggests that with carbon contents in the desirable range of 1.2 to 1.5 per cent, it would probably require a minimum of about 4.5 per cent manganese to retain a fully austenitic structure, under all service conditions, in solution treated light section castings. In heavier section castings, a somewhat higher manganese content would probably be necessary because of alloy segregation effects.

To further explore the properties of lean alloy austenites based on the use of carbon, manganese and molybdenum, and at the same time study the effects of copper and silicon additions, a second series of compositions was cast as Y-blocks and as 4½-in. balls. The balls from this series were worn-in, then tested together with the surviving groups from the first series in the wear test in one of the company's primary ball mills. Table 8 lists the compositions and results obtained. The compositions are listed in this table in their order of decreasing wear resistance (increasing abrasion factor).

It is significant that all of the steels in Table 8, with the exception of item 12, survived the wear-in and wear test without breakage. The 2.1 per cent silicon addition to item 12 is believed to be responsible for breakage of balls from this steel. An examination of their interior structure (from their recovered pieces) indicated a measurable amount of carbide precipitation and pearlite formation around the grain boundaries. Evidently the steel had insufficent hardenability as a result of the silicon addition.

The abrasion factors for items 5 and 6 indicate that silicon additions injure wear resistance of lean alloy austenites. Since silicon is not an austenite stabilizer, it is believed that its effect is to throw carbon out of solution which, in turn, reduces the wear resistance of the austenite.

The results from items 7 and 10 indicate that copper additions injure the wear resistance of the 5½ per cent manganese, austenitic steels. However, when copper is added to an austenitic steel composition, it should be permissible to lower the manganese content to some extent and still retain an austenitic structure. With lowered manganese, wear resistance should improve, so that manganese-copper combinations may be commercially feasible.

Additions Effect

From the wear tests on marked balls run to date at the authors' company, it has been possible to construct Fig. 8 which summarizes the influence of manganese, carbon, molybdenum and chromium plus molybdenum, on abrasion factors of solution treated austenitic steels. It is evident from this figure that best wear resistance is obtained in an austenitic steel when the manganese is low. It is further indicated that carbon should be at the highest level which can safely be retained in solution. A chromium addition to these steels improves their wear resistance but tends to embrittle them, so that wear resistance may be more effectively improved with less loss in toughness by reducing manganese than by adding chromium.

It is indicated in Fig. 8 that molybdenum additions moderately improve wear resistance. However, the economic justification for molybdenum in these steels comes mainly from its potent effect in suppressing embrittling types of carbides and pearlite in the austenite, rather than from its effect on wear resistance.

A desirable composition range from lean alloy austenitic steel castings, with a good combination of wear resistance and toughness, is indicated by the information in Table 8 and Fig. 8. On the basis of this information, a specification for the company's "6-1 alloy" has been adopted for ball mill liners, ball mill grates and certain other wearing parts in the mill and

TABLE 8 — RESULTS FROM SECOND SERIES OF LEAN ALLOY AUSTENITIC STEELS[1]

Item No.	Composition, %					Hardness[2]		0.2% Yield Str, psi	Tensile Str, psi	Elongation, %	Reduction of Area, %	Abrasion Factor[3]
	C	Mn	Si	Mo	Other	"A" (Bhn)	"B" (Rc)					
1	1.37	6.0	0.5	0.5	—	217	48	56,800	83,700	15.0	23.1	114
2	1.19	5.6	0.5	1.0	—	192	48	54,650	72,850	9.5	14.2	115
3	1.19	5.5	0.5	0.5	—	187	49	52,150	71,750	10.5	15.4	116
4	1.19	5.6	0.5	—	—	207	49	50,550	73,300	7.8	13.8	117
5	1.20	5.6	1.1	—	—	197	48	54,350	76,400	8.8	16.6	119
6	1.22	5.6	1.5	—	—	207	48	56,700	79,250	8.8	13.9	121
7	1.21	5.5	0.5	—	1.6 Cu	197	49	51,500	76,500	9.8	15.8	122
8	1.34	1.5	0.5	0.5	3.1 Cr, 10.0 Ni	241	47	58,700	84,000	9.5	11.3	127
9	1.34	12.0	0.5	0.5	3.0 Cr	228	46	68,400	106,900	18.0	16.0	128
10	1.22	5.7	0.5	—	3.1 Cu	192	47	53,500	80,750	12.8	17.7	129
11	1.34	12.0	0.5	0.5	—	217	47	59,900	105,400	26.0	31.5	136
12	1.22	5.7	2.1	—	—	217	44	60,950	83,000	8.2	11.2	broke

1) All groups solution treated by a water quench from 2000 F.
2) Hardness:
"A" (Bhn) is the hardness of the solution treated steel prior to any work hardening in service.
"B" (Rc) is the average Rc hardness on the worn surface of the test balls.
3) Abrasion factor is rate of wear relative to a factor of 100 for the 1.0% carbon Cr-Mo martensitic steel described under Table 7.

crushing plant. This specification is given in Table 9.

The molydenum content of 0.80-1.20 per cent in Table 9 has been chosen largely on the basis of its known metallurgical effects in austenitic manganese steel castings. Experience with Hadfield manganese steel production has indicated that when the manganese content drops below about 10 per cent, the castings tend to be brittle both in their as-cast and heat treated condition. This is mainly due to precipitation of embrittling-type carbides, and in some cases pearlite, around grain boundaries and along crystallographic planes.

Molybdenum is effective in suppressing these embrittling types of precipitates in both as-cast and heat treated castings. However, the range indicated in Table 9 is still somewhat arbitrary, even though it has given good results to date in commercial production of the 6-1 alloy. Possibly, for light section castings with simple shapes, a range lower than 0.80 to 1.20 per cent would be adequate. For heavy section castings or castings subject to welding, a range above 1.5 per cent molybdenum (such as is used in the 12-2 alloy) would be advisable.

6-1 ALLOY MICROSTRUCTURE

Figure 9 shows a representative microstructure of the solution treated 6-1 alloy. It is typical of an austenitic steel and closely resembles regular Hadfield steel, except possibly for its grain size. The 6-1 alloy will normally develop considerable pearlite during cooling and reheating while in its as-cast condition. The phase change occurring during subsequent solution treatment of the 6-1 alloy produces grain refinement, so that it tends to be finer grained than the regular Hadfield steel.

MECHANICAL PROPERTIES OF SOME 6 PER CENT MANGANESE STEELS

In Tables 7 and 8, the tensile properties and hardness of various modifications of the 6 per cent manganese steels, in their heat treated condition, are presented. It should be emphasized that the results were obtained from specimens cut from one in. thick Y-blocks and are, therefore, only representative of light section castings, heat treated individually. Since

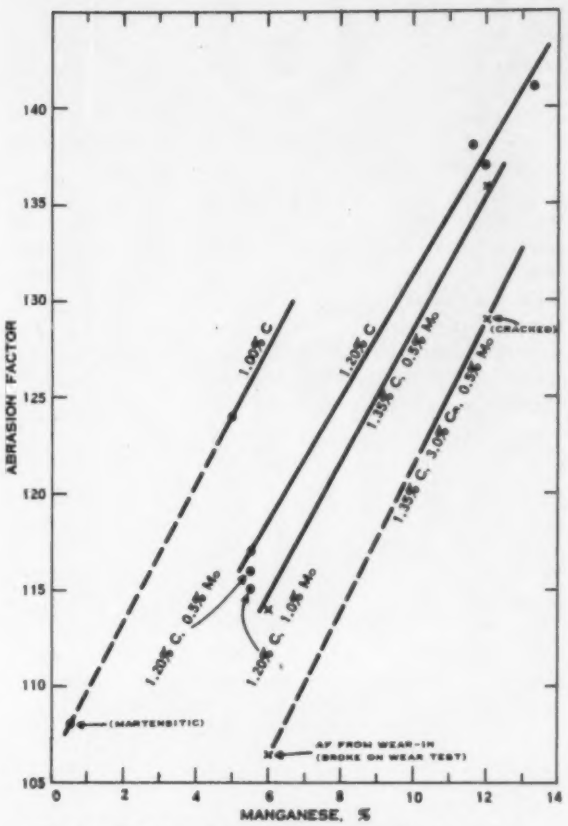

Fig. 8 — Relative abrasion factors at authors' company of austenitic steels with varying manganese contents.

TABLE 9 — SPECIFICATION OF "6-1 ALLOY" CASTINGS

1) Melting Furnace: Basic-lined electric or open-hearth.
2) Composition, %:

Carbon	1.25 - 1.40
Manganese	5.50 - 7.00
Silicon	0.40 - 0.70
Molybdenum	0.80 - 1.20
Phosphorus	0.05 max.

3) Treatment:
   a) Allow castings to cool slowly to room temperature or at least below 1000 F in their sand molds.
   b) Heat slowly to 1900 - 2000 F.
   c) Water quench.

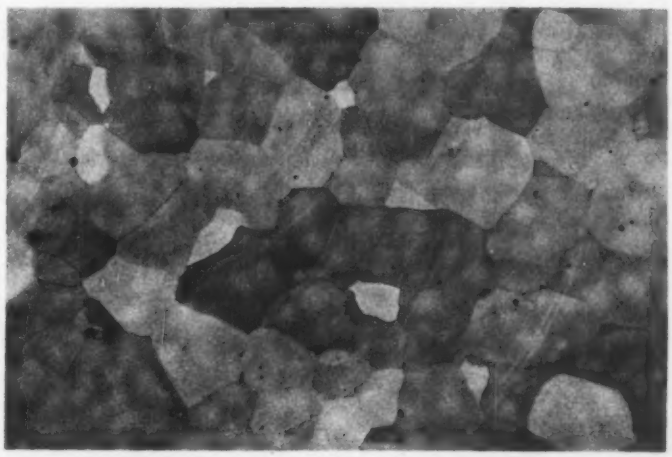

Fig. 9 — Microstructure of 6-1 steel. 1.2 per cent C, 5.6 per cent Mn, 1.03 per cent Mo, reheated to 2000 F for 3 hr, water quenched. 192 Bhn. 4 per cent picral etch. 100 ×.

these light section castings tend to cool rapidly, both after casting and during quenching, they do not have much opportunity to precipitate carbides or pearlite in their structure.

Consequently, the strength and ductility values given in Tables 7 and 8 should be interpreted with definite reservations. For example, reasonably good ductility was shown for the 3 per cent chromium modification (item 5, Table 7) and for the 2 per cent silicon modification (item 12, Table 8), yet these two steels broke when tested as 4½-in. diameter balls. The reason for this is evident from their microstructures, which indicate the balls from these compositions contained much greater amounts of grain boundary precipitates than the corresponding tensile specimens, as shown in Fig. 10.

THERMAL TREATMENT MODIFICATIONS EFFECT

In analogy with the 12 per cent manganese-2 per cent molybdenum composition, discussed previously, it was felt that a dispersion hardening treatment might be beneficial to the 6-1 alloy. Pearlitization in the 6-1 alloy is much more complete than in the 12-2 alloy. This, in turn, produced a more uniform dispersion of fine spheroidized carbides in the 6-1 alloy when it was dispersion hardened. However, when 4½-in. balls from this dispersion hardened 6-1 alloy were subjected to a ball mill wear test, the results were disappointing.

An abrasion factor of 121 was obtained, as compared to a factor of 115 for the same composition (1.19 per cent carbon) in the solution treated condition. Also, two of the four dispersion hardened balls broke in test.

It is obvious from this preliminary study of dispersion hardening of lean alloy austenites that the treatment will not improve resistance to high stress abrasion in grinding mills. This confirms a similar study made on the 12-2 alloy for grinding mill service. Apparently, when the grinding type of abrasion is involved, it is desirable to keep as much carbon as possible in solution in the austenite and depletion of carbon in solution to produce a carbide dispersion tends to injure wear resistance. A similar result has also been observed in the low alloy martensitic steels.

Under conditions of gouging, and also in scratching (low stress), abrasion where undissolved carbides in a structure have been found to improve wear-resistance, the dispersion hardened lean alloy austenites may still merit consideration. However, it appears that the composition of the steel should be adjusted to provide sufficient carbon and manganese for both the austenitic matrix and the undissolved carbides in the steel. Probably the carbon should be increased to at least 1.3 per cent and the manganese to about 8 per cent in order to obtain adequate toughness from a dispersion hardened, lean alloy austenite. Some data on 8 per cent manganese, dispersion hardened steels are given in Table 5.

6-1 ALLOY SERVICE PERFORMANCE

High Stress (Grinding) Abrasion

The characteristics of the 6-1 alloy, which include comparatively good abrasion factors, moderately good ductility and ready adaptability to economical commercial production, are such that it appears to be well-suited to use in most ball and rod mill liners, as well as in ball mill discharge grates. To evaluate this material in these applications, several sets of ball mill shell liners, end liners and discharge grates have been purchased and are on test in the company's primary ball mills.

In the discharge grates, performance of the 6-1 alloy to date has been outstanding. Wear measurements indicate the grates will have a life of 23 to 26 months as compared to a life of 11 to 12 months in the same service for the 0.5 to 0.6 per cent carbon, pearlitic chromium-molybdenum cast steel grates (250-300 Brinell) normally used in these mills. In addition, the 6-1 alloy grates show better peening characteristics on their wearing face, which is helpful in preventing plugging of the grate openings by worn steel balls.

In the ball mill shell liners, which are of "thin shiplap" design, wear measurements indicate the 6-1 alloy steel liners will have a life of approximately 4200 operating hr. A normal life is 3000 to 3300 hr for 0.80 to 0.90 per cent carbon pearlitic chromium-molybdenum steel (350-400 Brinell) and 3400 to 3800 hr for 0.65 to 0.75 per cent carbon, martensitic chromium-molybdenum steel liners of the same design in the same service.

The improvement in life from use of the 6-1 alloy is somewhat greater than would be indicated by abrasion factors obtained from large diameter test balls made from the 6-1 alloy and from the two types of chromium-molybdenum steel. It is believed that the inherently good depth hardening characteristic of the 6-1 alloy, when used in the comparatively heavy liner castings, is an important factor contributing to its good performance.

Gouging Abrasion

In applications involving gouging abrasion, fairly severe impact is often involved. Consequently, austenitic manganese steel of the Hadfield type, or one of its various modifications, is extensively used in such applications. For many of these applications, however, the lean alloy austenites should have adequate toughness, so their wear resistance under conditions of gouging abrasion is of interest. To evaluate this, the 6-1 alloy is being tested in grizzly screen sections, in jaw crusher liners and in ball mill scoop lips. In each of these applications, wear is believed to occur principally by gouging abrasion.

In the grizzly screens and jaw crushers, the 6-1 alloy appears to be giving satisfactory and possibly superior service, although no comparative wear rates are yet available. In the scoop lip application, one set of lips has been worn out and gave 9 weeks service, compared to a range of 4 to 7 weeks for regular Hadfield manganese steel lips in the same service. Figure 11 shows a picture of one of the worn 6-1 alloy lips. The dents in the leading edge of this lip are believed to be due to impacts from 3 in. diameter grinding balls which were fed daily into the scoop box. It is significant that no breakage occurred on these lips, even after they were worn to a thin metal section.

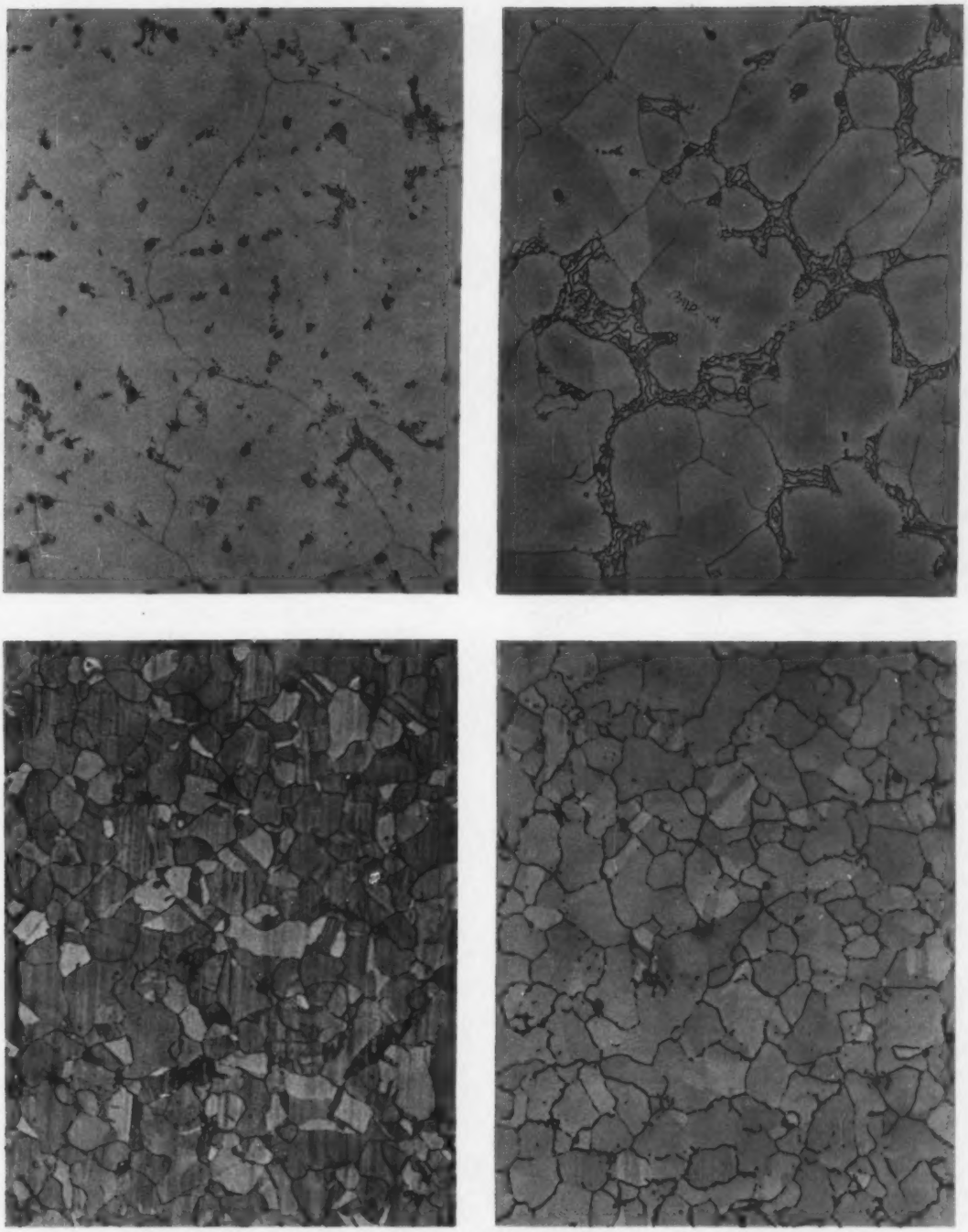

Fig. 10 — Microstructures of 6 Mn-3 Cr and 6 Mn-2 Si steels, water quenched from 2000 F. *Left* — one in. Y-blocks; *right* — 4½-in. balls. *Top row* — 1.35 per cent C, 5.90 per cent Mn, 0.5 per cent Si, 3.03 per cent Cr, 0.53 per cent Mo. *Bottom row* — 1.22 per cent C, 5.7 per cent Mn, 2.1 per cent Si. 4 per cent picral etch. 100 ×.

Low Stress (Scratching) Abrasion

Austenitic manganese steel normally has relatively poor resistance to scratching or low stress types of abrasion, but is used under certain conditions for such applications. An example is slurry pipe for backfilling mine stopes, where occasional bending stresses or rough handling might cause breakage of less ductile materials. The 6-1 alloy appears to be sufficiently promising in such applications that an evaluation of its relative resistance to scratching or erosive types of abrasion appears to be warranted.

SUMMARY AND CONCLUSIONS

As part of a program to improve the wear resistance of austenitic manganese steel, two basic approaches have been used. In one, carbide dispersions

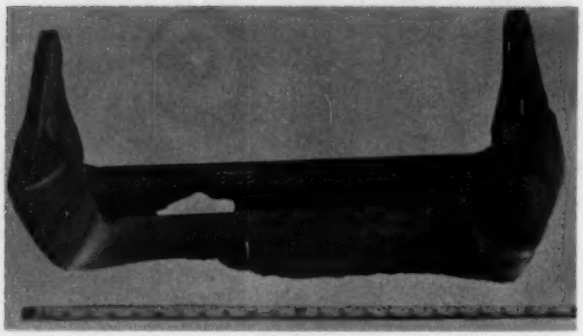

Fig. 11 — Worn scoop lip cast from 6-1 alloy.

in the austenite were developed by means of special alloy additions and modifications in heat treatment. In the other, less stable and more wear-resistant types of austenite were developed by the use of lean alloy, high carbon compositions.

Austenitic steels having a combination of good mechanical properties and improved resistance to gouging abrasion, as in cone crusher liners, are produced when carbide dispersions are developed in the 12 per cent manganese high carbon types of austenitic steel. The carbide dispersions, together with grain refinement, are obtained by combining a 2 per cent molybdenum addition with a special dispersion hardening heat treatment. This dispersion hardening heat treatment involves a pearlitizing treatment at 1100 F, followed by a re-austenitizing at temperatures ranging from 1700-1900 F.

The embrittling types of carbides which tend to form in high carbon austenitic steels are effectively suppressed by the addition of molybdenum in excess of about 1.5 per cent. Molybdenum additions to these steels permit the practical use of higher carbon contents, in a range of about 1.3 to 1.5 per cent and possibly higher. With these higher carbon contents, it is reasonable to expect further improvements in wear resistance.

Service experience with dispersion hardened, 12 per cent manganese-2 per cent molybdenum austenitic steel with a carbon range of 1.15 to 1.35 per cent, indicates that this type of steel has better wear resistance than the Hadfield or 2 per cent chromium types of austenitic manganese steel, when used in conditions involving gouging abrasion, such as in cone crusher liners. The dispersion hardened 12 per cent manganese-2 per cent molybdenum steel has exhibited improved mechanical properties in heavy section castings.

The mechanical properties and results of wear tests on various lean alloy types of austenitic steels are presented and discussed. It is shown that an austenitic steel with a combination of moderate ductility and improved wear resistance is obtained from a composition containing about 6 per cent manganese, 1 per cent molybdenum and 1.3 per cent carbon. This steel is solution treated by water quenching from 1900-2000 F.

Service tests in ball mill liners, grates, scoop lips and in jaw crusher liners and grizzly screens indicate the 6 per cent manganese, 1 per cent molybdenum, 1.3 per cent carbon steel, solution treated, has good abrasion resistance in both grinding and gouging types of abrasion. These tests have demonstrated that this austenitic steel is economically attractive for use in many wearing parts requiring a combination of moderate ductility and high wear resistance.

ACKNOWLEDGMENT

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The authors wish to express their appreciation to Dr. J. Z. Briggs, Director of Technical Information, Climax Molybdenum Co., for assistance in preparation of this paper.

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INFLUENCE OF NICKEL UP TO 37 PER CENT AND SILICON UP TO 3 PER CENT ON THE EUTECTIC CARBON CONTENT OF CAST IRON

by R. D. Schelleng

ABSTRACT

Nickel and silicon additions decrease the solubility of carbon in liquid iron. The magnitude of the decrease attributable to silicon has been known for many years. However, the prior data on the effect of nickel are quite meager. This report describes experiments which were carried out to evaluate the joint effects of nickel and silicon on the eutectic carbon content of iron over the ranges usually employed in cast iron. A formula describing these effects is given.

INTRODUCTION

Increasing use is being made of austenitic cast irons containing 20 to 35 per cent nickel. An addition of magnesium can be made to these irons to produce materials containing spheroidal graphite which makes the iron much stronger and tougher. Pumps, valves, exhaust manifolds, turbocharger casings and many other types of castings which require good quality control are made from such irons. Accurate knowledge of the combined effects of nickel and silicon on the eutectic carbon content of iron is essential to the foundry control of these alloys.

The literature on the iron-carbon-nickel system, at the levels of nickel of interest here, is quite limited. Two investigations of the effect of nickel on the eutectic carbon content have been reported. The results of these investigations by Schichtel and Piwowarsky[1] and Kasé[2] are not in agreement. In reviewing these two studies Marsh[3] could not decide which, or if either, data were reliable. Schichtel and Piwowarsky studied the joint effects of nickel and silicon on the eutectic carbon content, but their experiments were limited to a maximum of about 15 per cent nickel.

Both the iron-graphite and nickel-graphite binary systems exhibit eutectics. Since iron and nickel are mutually soluble, the liquidus surface of the ternary iron-nickel-graphite system exhibits a eutectic trough extending from one binary eutectic point to the other. The effect of silicon in decreasing the eutectic carbon content of iron is well known. This investigation was undertaken to obtain quantitative data on the joint effects of nickel and silicon on the eutectic carbon content of cast iron. Nickel contents up to 37 per cent in conjunction with silicon up to 3 per cent were studied.

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PROCEDURE

The cope surface segregation of carbon in ductile iron in excess of the solubility limit is well known.[4] It was observed in the course of other work that in a large casting requiring 2½ hr to solidify this segregation is complete. Careful analyses for carbon and silicon from the body of such castings showed that the composition invariably conforms to the eutectic carbon value. The eutectic carbon content is defined by the following formula, which has been used for many years to describe the effect of silicon on the eutectic carbon content of iron:

$$C_{eutectic} = 4.30 - 0.33\ (\%\ Si)$$

Proper procedure in obtaining samples for carbon analyses must be employed because graphite can be lost mechanically from samples of small particle size. All samples for determination of carbon in this investigation consisted of particles measuring 1/32 to 1/16-in. thick by about 1/8 to 3/16-in. square.

It has been noted that the graphite spheroids in hypoeutectic ductile irons tend to occur in straight lines.[5] In heavy hypereutectic castings these lines of spheroids become zones of heavy concentration of spheroids.[6] Such zones occur throughout the casting, and should not be confused with the segregation of excess hypereutectic graphite at the cope surface. The zones are formed by the upward flotation of graphite spheroids, which are trapped by austenite dendrites. The zones tend to be horizontal and rather far apart depending upon the solidification rate. In an effort to avoid any error in analysis caused by this graphite segregation, the particles for carbon determinations were cut from the castings in such a way that the longer dimension lay in a vertical direction. Thus, the particle would span several of the horizontal graphite layers in the structure.

Carbon and Silicon Analyses

Since the utilization of large castings for the program would be impractical, ductile iron containing no nickel was cast into a series of bars of various sizes.

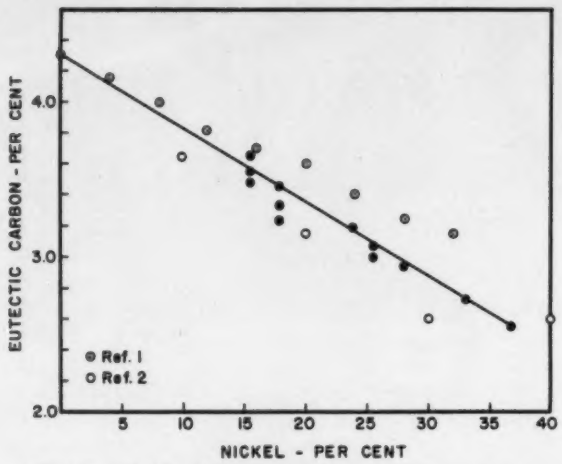

Fig. 1 — Nickel effect on the eutectic carbon content of iron.

NICKEL AND SILICON EFFECT ON SATURATION CARBON CONTENT OF IRON

Melt No.	C_s	Si	Ni
25280-1	3.55	N.F.	15.4
	3.46		
	3.65		
25280-2	3.33	N.F.	17.8
	3.23		
	3.45		
25281-1	3.19	N.F.	23.9
-2	2.94	N.F.	28.0
25282-1	2.73	0.45	33.1
-2	2.55	0.42	36.8
25288	3.01	0.25	25.5
	3.01		
	3.07		
25286-1	3.15	0.98	19.3
-2	2.96	1.86	19.1
25287-1	2.83	2.38	19.5
-2	2.56	3.65	19.6
25947	2.66	1.07	29.6
	2.75		
25948	2.59	1.60	29.9
25949	2.55	2.14	29.9
	2.63		
25950	2.30	2.68	29.7
	2.45		
25951	2.30	3.13	30.4
25955	2.71	0.92	31.8
	2.58		
25956	2.63	1.27	30.1
25957	2.63	1.83	30.0
	2.42		
25958	2.50	2.13	29.9
24309	2.30	2.65	30.0
	2.34		
24311	2.57	0.80	33.6
	2.62		
24789	2.50	1.15	34.4
24790	2.42	1.71	34.3
24791	2.35	2.05	34.1
	2.52		
24792	2.29	2.51	34.3

Carbon and silicon analyses were obtained in order to determine if a smaller size casting would be suitable. The following values were obtained from near the bottom of a casting 2¾-in. in diameter and 8½-in. high:

C, %	Si, %
3.5	2.37
3.63	
3.41	
3.67	

The average of these carbon values (3.57 per cent) and the silicon content fit the formula given above, and the casting was considered to be satisfactory.

A considerable number of high-carbon melts were made with varying silicon and nickel contents. Carbon analyses from near the bottoms of the cylinders were correlated with the nickel and silicon contents. Since the values obtained did not agree with either prior investigation when extrapolated to zero silicon, additional melts were made in which silicon was absent. Since nickel is a graphitizer, no significant amount of carbide was encountered, and all melts solidified according to the stable metal-graphite system.

The charge materials for the latter melts were ingot iron, electrolytic nickel and graphite. A small amount of silicon was necessary for deoxidation prior to the addition of the graphite in order to control the melt. The melts containing silicon were made from pig iron of low phosphorus and manganese contents, nickel and ferrosilicon. All melts were treated with one per cent nickel-magnesium alloy to spheroidize the graphite, and the melts in which silicon was studied were inoculated with 0.5 per cent silicon. The melting unit was a 30-lb induction furnace with a magnesia lining.

RESULTS AND DISCUSSION

The effect of nickel in decreasing the eutectic carbon content of iron was found to be approximately linear up to about 37 per cent nickel, as shown in Fig. 1. If the accepted value of 4.30 per cent carbon in the absence of nickel is included with these data, the rate of decrease is 0.047 per cent carbon/per cent nickel. Complete data on these and all other melts are presented in the table. Eutectic carbon values determined in this investigation are approximately midway between the rather divergent values reported in the literature. Kasé's determinations are lower, while Schichtel and Piwowarsky's are higher.

Three series of melts of approximately constant nickel and varying silicon contents were made. These melts contained nominally 20, 30 and 34 per cent nickel. Over the silicon range employed, an essentially linear effect of silicon on the eutectic carbon content was observed at each particular nickel level, as is shown in Fig. 2. However, the magnitude of the effect of silicon varied with nickel content. At 20 per cent nickel, the eutectic carbon content is decreased at

the rate of 0.22 per cent for each per cent of silicon added.

At 34 per cent nickel, this rate becomes 0.14 per cent. The data at 30 per cent nickel exhibit an unexplainable, greater scatter than at the other two nickel levels. For this reason the rate of decrease of carbon with increasing silicon was determined statistically and found to be 0.19 per cent for each per cent silicon. As shown in the inset of Fig. 2, these slope values, in conjunction with the usual value of 0.33 per cent at zero nickel, vary approximately linearly with nickel content.

Schichtel and Piwowarsky determined the maximum solubility of carbon in the melt as a function of nickel and silicon contents and temperature. These carbon solubility values for a particular nickel and silicon composition were plotted versus temperature. Extrapolation of such data to the temperature at which freezing began gave values for the eutectic carbon content.

The different experimental method used resulted in values somewhat different from those found in this study. However, the trend of Schichtel and Piwowarsky's data substantiates the present finding that the influence of silicon decreases with increasing nickel content.

The observed effects of nickel and silicon on the eutectic carbon content can be expressed by the following formula:

$$C_{eutectic} = 4.30 - 0.33\,(\%Si) - 0.047\,(\%Ni) + 0.0055\,(\%Ni)\,(\%Si)$$

This formula is valid only for nickel contents up to 37 per cent and silicon contents up to 3 per cent. The 95 per cent confidence limit (twice the standard error of estimate) is ± 0.16 per cent carbon. Figure 3 presents the relationship graphically at nickel levels pertinent to the common grades of austenitic cast iron.

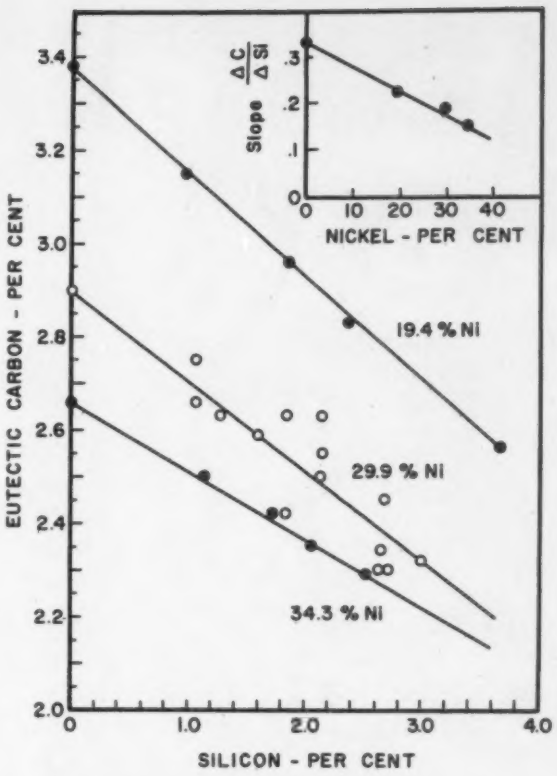

Fig. 2 — Effect of silicon at various levels on the eutectic carbon content of iron.

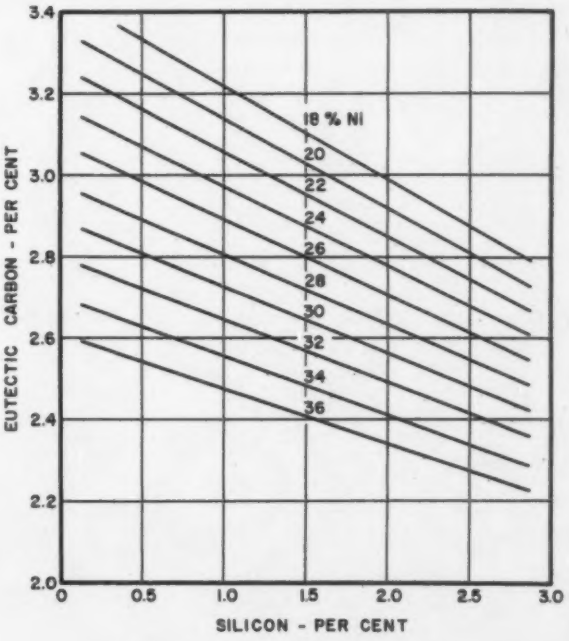

Fig. 3 — Graphical presentation of the formula for eutectic carbon content determined in this investigation at nickel levels pertinent to the common grades of austenitic cast iron.
$C_e = 4.30\% - 0.33\ (\%\ Si) - 0.047\ (\%\ Ni) + 0.0055\ (\%\ Ni)\ (\%\ Si) \pm 0.16\%$

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RAMMING AND CLAY CONTENT EFFECT ON HOT COMPRESSION STRENGTH OF MOLDING SAND

by R. W. Heine, J. S. Schumacher, W. F. Shaw and E. H. King

ABSTRACT

In foundry usage, molding sands are exposed to temperatures ranging from atmospheric to over 3000 F. The behavior of sands and molds at elevated temperatures is generally agreed to importantly affect the quality of castings made. However, the principles of behavior of sands at elevated temperature, the properties of a wide range of compositions of sand-clay mixtures and their relationship to casting quality have been evaluated only to a limited extent. Basic information on principles of the effects of clay content, and type and amount of ramming on elevated temperature properties of simple sand-clay-water mixtures, is needed. This paper presents such information for the hot compressive strength property.

REVIEW OF PAST WORK

A number of investigations of various elevated temperature properties of sands have been reported in the literature.[1-17] Most of the reports[1-14] show examples of hot compressive strength vs. temperature curves of the kind shown schematically in Fig. 1.

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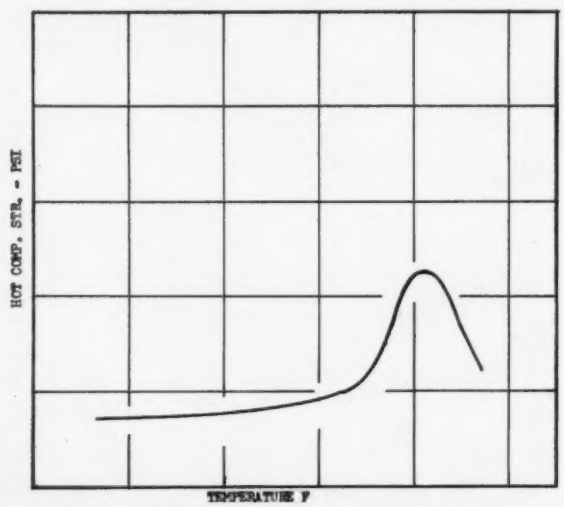

Fig. 1 — Schematic diagram of usual relationship of hot compressive strength and temperature of testing.

The source of strength at various temperature levels has not been proved. However, the mechanisms suggested appear to be sound. At low temperatures (below 1000 F) hot strength is ascribed to the dry strength developed from the evaporation of moisture.[1,2] Thus, increased dry strength from increased moisture content results in increased hot strength in this temperature range.[1,2]

As temperatures increase toward about 1750 F, clay forms a viscous glass from fusion,[1] and causes the large increase in hot strength, shown in Fig. 1. Further, increase in temperature toward 2000 F and above is accompanied by a decrease in viscosity of the fused clay and a large drop in strength, as shown on Fig. 1. Reference one indicates maximum hot compressive strength occurring at 1600, 1750 and 2050 for southern bentonite, western bentonite and fireclay bonded mixtures, respectively. The general type curve (Fig. 1) may display some other minima, plateaus and maxima,[1,2] but these seem of minor consequence.

The literature appears in agreement as to the effect of clay content on hot compressive strength. An increase in clay content is said to raise the hot strength vs. temperature curve. For example, curves for 1, 2 and 4 per cent western bentonite all at 3 per cent moisture are compared.[2] The reference[2] shows hot strength curves are raised by 50 per cent when the per cent clay is doubled from 2 to 4 per cent. However, the literature has been concerned with limited clay contents. The present paper will show that beyond a certain percentage, increasing bentonite clay content will actually lower the hot strength of a sand.

Comparison of the effect of common foundry clays on hot strength can be found in various references.[1,2,5,6,7,9,10,11,13,14,16] It is generally agreed by these authors that western bentonite imparts the greatest hot strength, southern bentonite the lowest and fireclay intermediate hot strength. While this is no doubt true, the comparisons were based on mixtures containing equal percentages of clays. Since equal percentages of these clays are seldom used in foundry sands, comparisons should be based on a wider range of clay contents than the literature offers. Temperature of comparison is also important since the clays are reported to exhibit

TABLE 1 — SAND MIXTURES USED FOR HOT COMPRESSIVE STRENGTH TESTS

Mixture Type	Sand	Clay Type and Per cent	H_2O, %
1	67.9 AFS Silica*	W. Bent. — 1.0, no additives	2.10
	67.9 AFS Silica*	3.0	2.10
	67.9 AFS Silica*	6.0	2.7-2.9
	67.9 AFS Silica*	8.0	3.1-3.2
	67.9 AFS Silica*	20.0	5.0
2	67.9 AFS Silica*	S. Bent. — 4.0	2.3
		6.0	2.8
		8.0	3.0
3	None	W. Bent. 86.9	13.1
	None	S. Bent. 86.2	13.8
	None	Fire clay 90.1	9.9
4	Iron Foundry, 68 AFS No.	W. Bent. 9.8% AFS Clay 5.5% Combustible	2.9
5	Iron Foundry, 78 AFS No.	S. Bent. 12.5% AFS Clay 6.2% Combustible	4.4
6	Iron Foundry, 61.6 AFS No.	Fire clay 12.8% AFS Clay 6.6% Combustible	4.8
7	67.9 AFS Silica*	Fire clay, 10%	3.4
		15%	4.5

*Sieve No. 40 — 1.6% retained.
50 — 14.7
70 — 31.7
100 — 31.4
140 — 15.1
200 — 4.4
pan — 0.9

their maximum hot strengths at different temperature, as pointed out previously.

The effects of additives have also been considered. References[2,16] suggest that hot strength is lowered at all temperatures by organic additive such as cereal, seacoal, wood flour, etc.

The foregoing observations pertain to sand specimens heated slowly and held at a soaking temperature prior to testing. Rapid heating has also been employed and its advantages cited.[3] Testing after holding at temperature permits an approach to equilibrium, and this is the purpose of such studies and also of this investigation. The aims of the other technique will not be contested here, but they are not the purpose of this study.

EXPERIMENTAL PROCEDURE

Sand mixtures were prepared in a vertical wheel laboratory muller using 4500 gram batches. The mixtures were dry mulled 2 min and mulled 10 min after adding the water. Moisture in the mixtures was intended to be in the range of +10 to 30 per cent free water according to the calculation method of reference 18. The mixtures listed in Table 1 were prepared and tested for high temperature properties. The base sand consisted of 68-70 AFS silica sand. The clay content and type was varied as shown in the table. All sand was put through a No. 6 sieve after mixing. Standard AFS specimens 1⅛-in. diameter × 2 in. length were prepared.

In addition, approximately 60 specimens from each batch were made varying in green mold hardness from 60 to 95, and in specimen bulk density from about 75 to 100 lb/cu ft. Low mold hardness specimens were prepared using a special rammer having a 1.69 lb weight dropped from a height of ⅜-in. The number of rams with this weight was generally about 30, 11 and 1; the objective being to prepare specimens of approximately 60, 70 and 80-85 mold hardness. Average mold hardness was obtained from one reading on each end of the specimen. The remaining sand was used to determine green and dry properties of the mixture in order to compare them with similar mixtures previously studied and tested.

Hot compressive strengths of the specimens were determined in a dilatometer type furnace. Tests were conducted on green specimens using an own-atmosphere hood. A number of tests made with pre-dried specimens indicated no effect of predrying. A soaking time (time lapse between introduction of specimen and turning on of loading pump) of 12 min was used. Pump loading rate was adjusted so that the time lag between the time the pump was turned on and the time the load was first applied to the specimen was one min and 20 sec ±5. The total specimen heating time before loading took place was then approximately 13⅓-min.

Most tests were conducted at 500, 1000, 1500 and 2000 F. Intermediate temperatures were also used where it was deemed desirable. These temperatures may be seen as points of data on the graphs. At least two samples were tested for each point of data shown on the graphs. The data are presented graphically in Figs. 2 through 7. The hot compressive strength at the temperature where the maximum occurs, about 1750 F for bentonite and 2000 to 2200 F for fireclay, was not determined except in a few cases. The difficulty of obtaining the exact maximum and the fact that many of the standard specimens had a strength in excess of the capacity of the machine (1000 lb load) caused the authors to avoid testing in the maximum strength temperature range.

Breakage of the specimen hood from overloading also occurred. Testing at a number of temperatures above those of maximum strength was also avoided because plasticity caused plastic bulging under load to the point where the specimens became stuck in the hood. The temperature of 2000 F was selected as a testing temperature because it is above that of maximum strength, but does not permit sufficient bulging of the sample to destroy the own-atmosphere hood.

RAMMING EFFECTS

A green mold hardness range of 60 to 95 and specimen bulk density range of about 70 to 105 lb/cu ft was obtained from variation in ramming by the methods described earlier. Hot compressive strength at 500, 1000, 1500 and 2000 F is related to green mold hardness of various western bentonite, southern bentonite and fireclay bonded mixtures, as shown in Figs. 2, 3 and 4, respectively. Figures 5, 6 and 7 show the relation of hot compressive strength to bulk density for the same mixtures. The mixtures tested are those listed in Table 1, and indicated by clay content and type on the respective graphs, Figs. 2-7.

The range of ramming energies used to produce the mold hardness and density ranges varied from one ram with a 1.69 lb weight dropped ⅜-in. for the minimum, to 3 to 5 rams of the 7 lb weight dropped

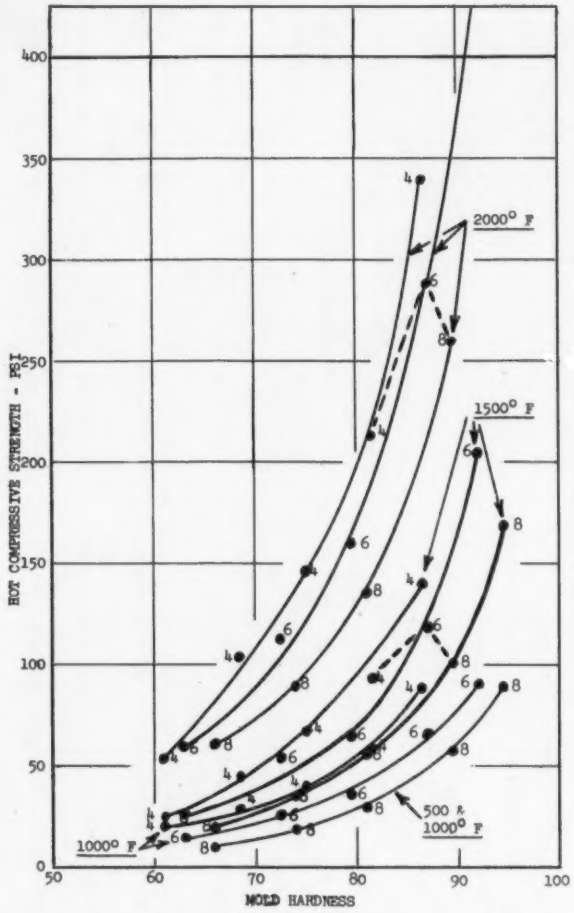

Fig. 2 — Hot compressive strength — mold hardness relationship for sands containing 4, 6 and 8 per cent southern bentonite.

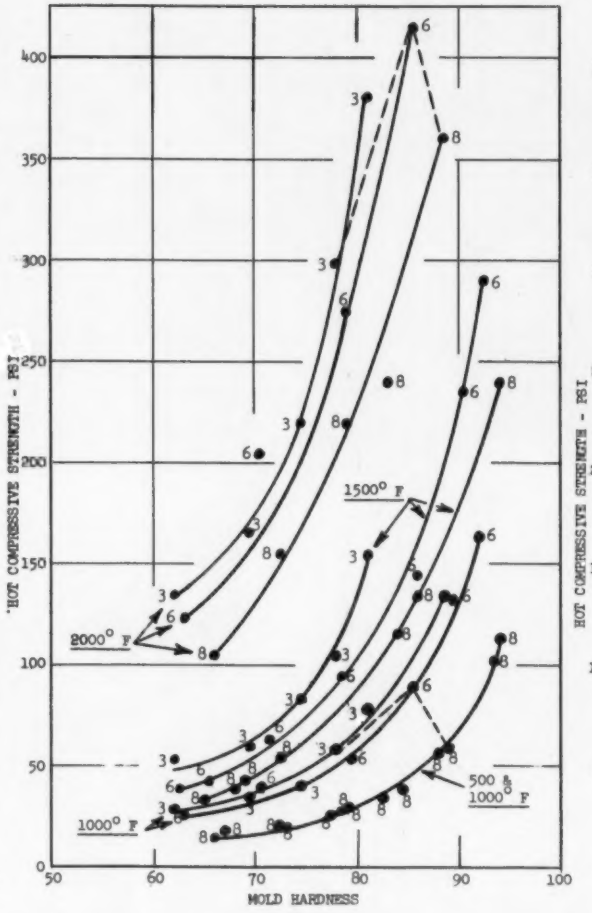

Fig. 3 — Hot compressive strength — mold hardness relationship for sands containing 3, 6 and 8 per cent western bentonite.

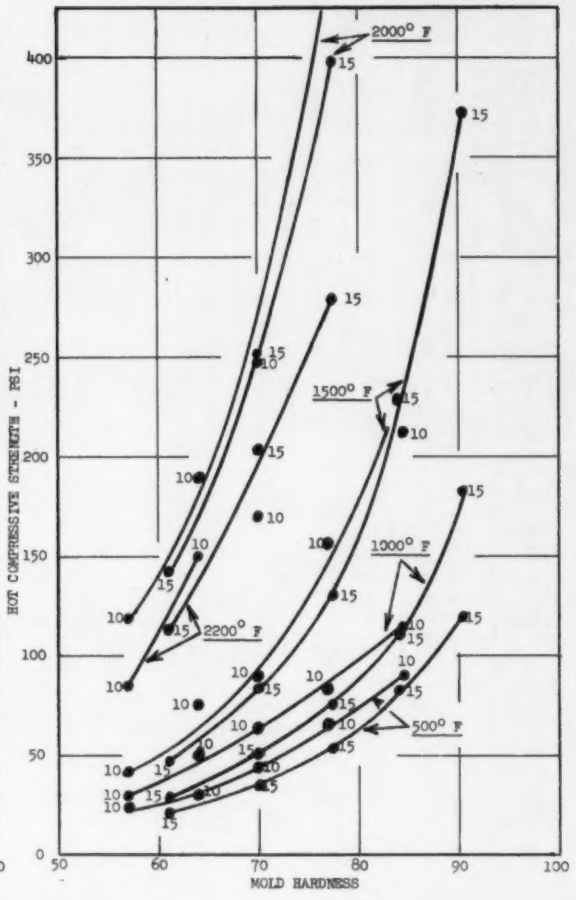

Fig. 4 — Hot compressive strength — mold hardness relationship for sands containing 10 to 15 per cent fire clay.

2⅝-in. for the maximum. The graphs show that at all clay contents and temperatures of testing, hot compressive strengths increase rapidly with increasing mold hardness and bulk density (in other words with increasing ramming). The increment of increase in hot strength at 500, 1000 and 1500 F caused by increasing ramming is greater when mold hardness exceeds 80 to 85 lb/cu ft, and bulk density exceeds about 85 to 90 lb/cu ft, than it is at lower levels of hardness and density.

Ramming to low mold hardness of 60 to 70, and low bulk density of 70-80 lb/cu ft causes all hot compressive strength values to be low at all clay contents. At 2000 F, where clay fusion is dominant, hot strength increases rapidly and uniformly with increasing mold hardness and bulk density in all the mixtures.

The combined effects of ramming and temperature of testing can also be observed on Figs. 2 through 7. The effect of temperature can be better observed on Figs. 8 and 9, however, and these will be discussed later.

Comparison of Figs. 5, 6 and 7, with 2, 3 and 4, indicates that hot compressive strength increases more gradually with increasing bulk density than with mold hardness. A unit increase in mold hardness is accompanied by a larger increase in strength than a unit increase in bulk density. The green mold hardness test should then be a sensitive indirect measurement of hot compressive strength of a particular sand. This point is emphasized again in Figs. 8 and 9 for western bentonite bonded sands. Similar graphs were produced for the other clay bonds, but they will not be shown here. In these figures, mold hardness of the specimen is fixed at 80 in Fig. 8 and 90 in Fig. 9. The effect of temperature on hot compressive strength at constant mold hardness is shown in these figures.

Little increase in hot strength and no decrease occurs with increasing testing temperature until a temperature of 1000 F is exceeded. An increase in hot strength occurs between 1000 and 1500 F. The increase is larger in fireclay bonded sands and smaller in bentonite bonded sands, as seen on Figs. 8 and 9. Above 1500 F and below 2000 F in the bentonite bonded sands tested, maximum hot strength occurs. This maximum strength was not determined for reasons of equipment limitations cited earlier. The temperature range of maximum strength is indicated as a discontinuity in the curves on Figs. 8 and 9. At 2000 F, hot strength is seen to be above that at 1500 F for western bentonite even though this is in the temperature range of decreasing strength due to clay fusion.

The foregoing effect of temperatue on hot compressive strength is based on comparisons at constant mold

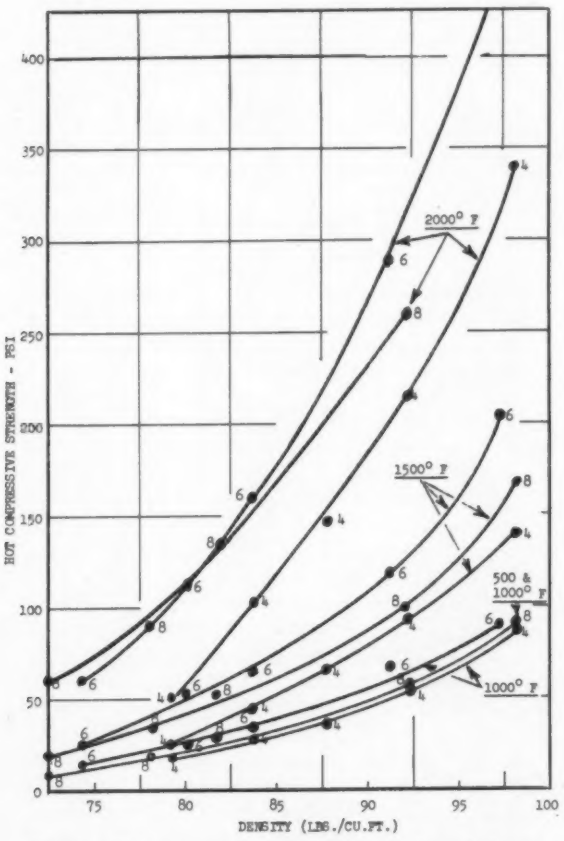

Fig. 5 — Hot compressive strength — density relationship for sands containing 4, 6 and 8 per cent southern bentonite.

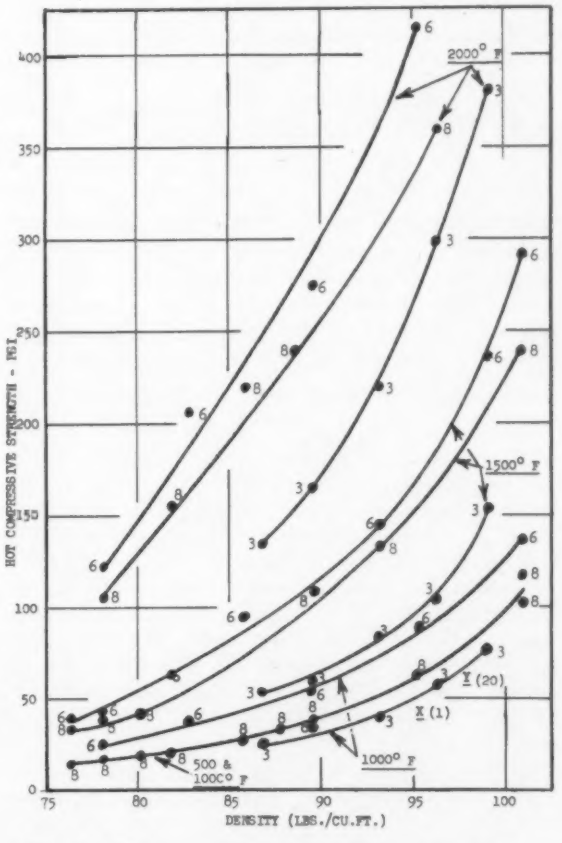

Fig. 6 — Hot compressive strength — density relationship for sands containing 3, 6 and 8 per cent western bentonite.

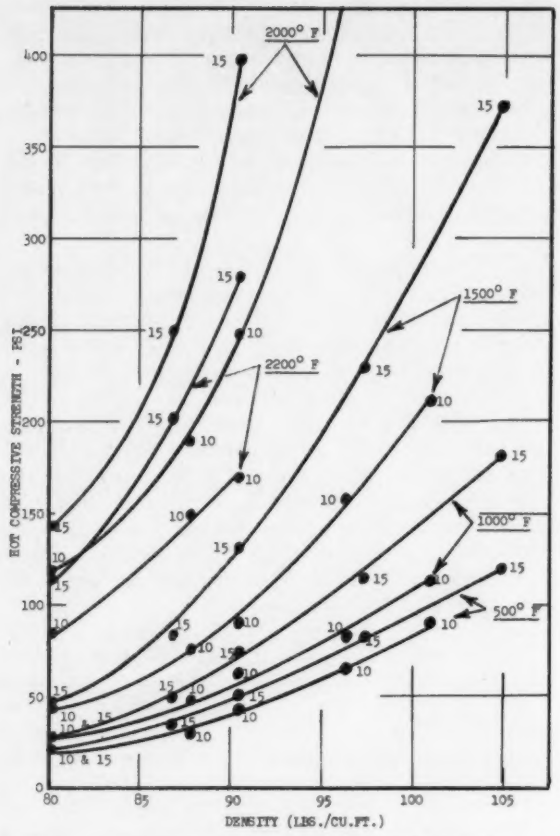

Fig. 7 — Hot compressive strength — density relationship for sands containing 10 and 15 per cent fire clay.

hardness. However, it should be recognized that low clay content sands ram to a lower mold hardness then do higher clay content sands at a constant ramming energy. The effects of testing temperature and ramming energy therefore must also be interpreted in the light of the effect of clay content at constant ramming energy as well as variable ramming energy.

CLAY CONTENT AND TYPE EFFECT

Examination of Figs. 2 through 4 shows that in every case the sand mixtures with lowest clay content had the highest hot compressive strength at a given mold hardness and temperature. This seems contrary to previous reports. However, the effect of clay content on hot strength depends on its effect on response to ramming (mold hardness and density achieved) as well as its bonding ability. At constant ramming energy, increasing mold hardness occurs with increasing clay content up to a limit. For example, Figs. 2 and 3 points of equal ramming energy, one 7-lb ram dropped 2⅝-in., have been connected by a dotted line.

At this constant ramming energy, mold hardness is seen to increase with increase in southern bentonite from 4 to 6 to 8 per cent, and western bentonite from 3 to 6 to 8 per cent. However, hot compressive strength is seen to first increase with clay content and then decrease with clay content. There is then at any temperature, an optimum clay content for maximum hot compressive strength in bentonite bonded sands when the ramming energy is held constant. This is most analogous to foundry operation in which the number of jolts and squeeze pressure (ramming conditions) are usually held constant within limits.

This is further demonstrated in Fig. 10 where the 1500 F hot compressive strength of one 7-lb—2⅝-in. ram sample of western bentonite bonded sand is shown as a function of clay content. The optimum western bentonite percentage for maximum hot compressive strength appears to be about 6 per cent at all temperatures tested. This is true when the comparison is made at constant density as well as constant ramming energy. Fire clay bonded mixtures display a different effect of clay content on hot strength than does western bentonite, as shown in Fig. 10. Hot strength increases with increasing clay content at constant ramming energy until a maximum is reached which is comparable to the hot strength of the clay itself.

Hot Compressive Strength Decrease

If the effect of clay content is considered at constant mold hardness rather than constant ramming energy, the relationships shown in Fig. 11 exist.

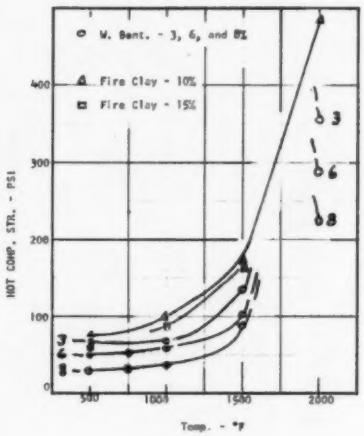

Fig. 8 — Relationship of hot compressive strength to testing temperature at constant mold hardness of 80.

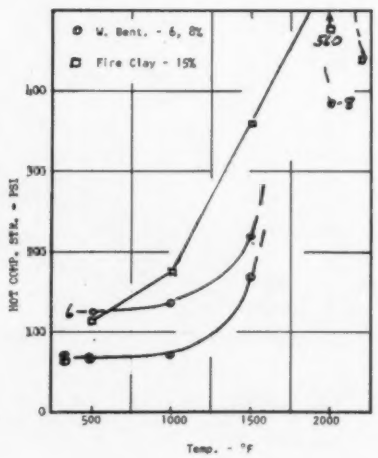

Fig. 9 — Relationship of hot compressive strength to testing temperature at constant mold hardness of 90.

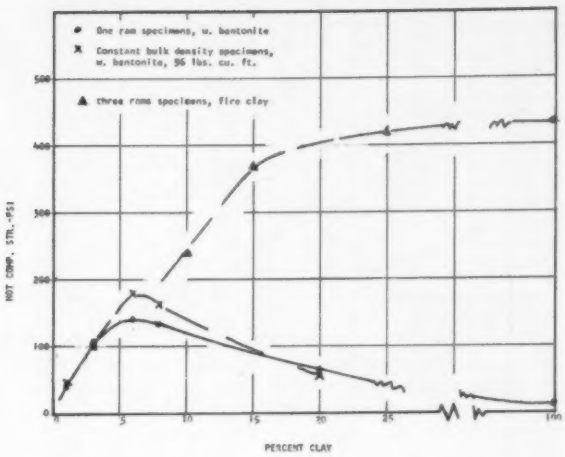
One ram specimens, w. bentonite
Constant bulk density specimens, w. bentonite, 96 lbs. cu. ft.
three rams specimens, fire clay
HOT COMP. STR.-PSI
PERCENT CLAY

Fig. 10 — Relationship of hot compressive strength to per cent clay for western bentonite and fire clay sands at constant remming energy of one and 3-7 lb — 2⅝-in. rams. A comparison at constant bulk density is also shown for western bentonite. Temperature equals 1500 F.

Here hot compressive strength decreases continually with increasing clay in the range of 3 to 8 per cent bentonite at a constant mold hardness of 80. The mold hardness of 80 was selected for comparison because of the high ramming energy required to reach 80 or higher in sands containing as little as 3.0 per cent bentonite as shown in Table 2.

TABLE 2 — RAMMING REQUIRED TO REACH 80 MOLD HARDNESS

Clay, %	H_2O, %	Spec. Wt., gm.	No. of 7 lb — 2⅝-in. rams	No. of 1.69 lb — ¾-in. rams
1.0 W. Bent.	2.1	50.0	80 M.H. not reached with 3	
3.0 W. Bent.	1.9-2.1	50.5	1-3	Over 50
6.0 W. Bent.	2.6-2.9	46-47	Not needed	35-40
8.0 W. Bent.	2.9-3.2	45.0-45.5	Not needed	18-23

An optimum clay content which produces maximum hot compressive strength thus does not appear on Fig. 11, and instead it appears that hot strength decreases continually with increasing clay content at constant mold hardness. However, it must be realized that a low clay content sand is rammed to a higher density at 80 mold hardness than is a high clay content sand, as shown by specimen weight in Table 2, because of the greater ramming energy required to produce 80 mold hardness at the lower clay content. This was pointed out previously in Fig. 10, where it was shown that at equal density (96 lb/cu ft), produced by ramming the high clay content sand harder, the optimum clay content still exists at about 6 per cent western bentonite.

The foregoing data show that hot strength test results must be carefully interpreted in terms of ramming energy, clay content and mold hardness. When the ramming energy and density are held constant, there is a bentonite content for maximum hot strength. In the foundry, ramming energy is held constant by a fixed number of jolts and squeeze pressure or other molding method. Higher mold hardness achieved by an increase in clay content at fixed ramming energy will be accompanied by an increase in hot strength until the optimum clay content is reached.

Beyond the optimum, further increase in mold hardness caused by increased clay content at constant ramming energy will cause a decrease in hot strength. If comparisons are made at constant mold hardness, then the difference in ramming energy (and density) required to reach a given mold hardness must be considered. Mold hardness comparisons without these considerations are not valid. The effect of moisture content in changing response to ramming is a further qualification since this work was done with moisture controlled, as previously stated, to produce favorable response to ramming.

However, for a particular sand mixture, including its moisture, increasing mold hardness still means rapidly increasing hot strength due to increasing density caused by greater ramming.

Clay Testing

The reason for differences in the effect of clay type on hot strength under constant ramming energy is ex-

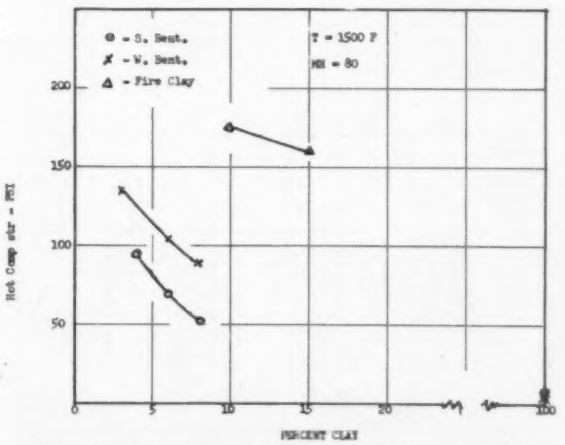

Fig. 11 — Clay content effect on hot compressive strength at 1500 F when specimens of constant 80 mold hardness are tested.

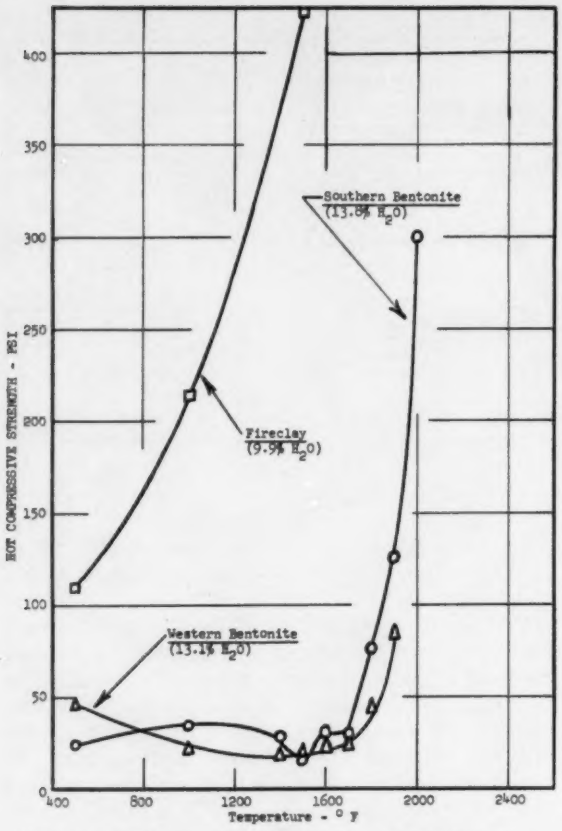

Fig. 12 — Hot compressive strength — temperature relationship for three-ram specimens of clay-water mixtures.

plained by testing the clay itself in the absence of sand. Batches of clay and water composed of 86.2 per cent southern bentonite—13.8 per cent H_2O, 86.9 per cent western bentonite—13.1 per cent H_2O, and 90.1 per cent fire clay—9.9 per cent water were prepared and tested, with results shown in Fig. 12. The standard 3 rams AFS hot strength specimen was used. The fire clay specimens weighed 60 grams, the western bentonite weighed 49 grams and the southern bentonite 46 grams. Fig. 12 shows fire clay displays a continual increase in hot strength with increasing temperature.

Tests could not be made above 1600 F with fire clay, as the specimens exceeded the load limit of the testing machine. The bentonites behave quite differently than fire clay. They appear weaker although the difference in density causes some of the lower strength. Little increase in hot strength occurred in the bentonite until a temperature above 1500 F was reached. Here plasticity during testing appeared, and a large increase in strength occurred. Temperatures over 1900 F were not used, for reasons cited earlier.

The behavior of the clays then agrees with the behavior of the sand-clay mixture. Bentonite and mixtures show little change from dry strength properties from 212 F up to about 1500 F. Plasticity begins at about 1600 F (perhaps slightly at 1400 F in sand-clay water mixtures[1,2]). A peak strength is reached at 1600 to 1800 F because of a combination of mechanical interlocking of sand grains and the viscous clay fusion bond. Higher temperatures, especially above 2000 F, cause diminishing strength due to increased fusion. Fire clay, however, displays a different behavior. A continual increase in strength is observed with increasing temperature until plasticity develops at about 2000 F to 2200 F. A decrease in hot strength then occurs. Thus it is evident that sand mixtures based on these clays display hot strength characteristics derived from the clay itself.

HOT STRENGTH OF FOUNDRY SANDS

The hot compressive strength of some gray iron foundry sands were studied for comparison with the simple sand-clay-water mixtures. Sands bonded with a single clay, fire clay, western or southern bentonite, were selected to avoid the effects of multiple clay bonds. However, these sands all contained carbonaceous matter from various additives in the amount listed in Table 1. The graphs of hot compressive strength at 500, 1000, 1500, 2000 F vs. green mold hardness are shown in Figs. 13-15. Obviously, the carbonaceous matter had had a tremendous effect on reducing hot compressive strength, especially at 1500 and 2000 F.

Further, little plasticity was noted at 2000 F even in the bentonite bonded sands. Also, the differences expected from the three types of clay bond do not appear in the curves. Either fusion was prevented

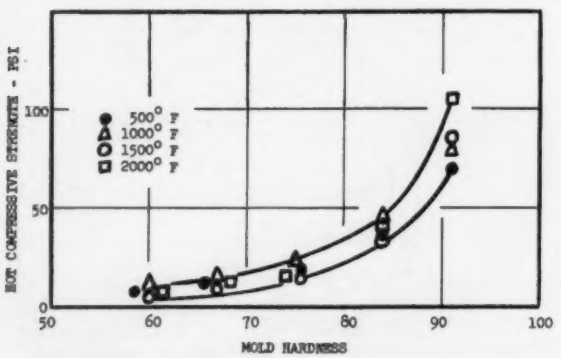

Fig. 13 — Hot compressive strength — mold hardness relationship for an actual foundry molding sand bonded with fire clay.

from establishing a viscous clay bond by the carbon present, or the entire process was delayed longer than the soaking time used for testing, 13 min and 20 sec total. This soaking time did not cause burning out or volatilization of the carbonaceous matter in the own-atmosphere method of testing used. The large reduction in hot strength evident in comparisons of the foundry sands with the new sand mixtures requires research into the effects of additives. The references in the review of past work provide some information on the subject, but only in a limited number of mixtures.

SUMMARY

The authors have shown that increased ramming can raise hot compressive strength of any sand mixture by about 4 to 10 times, depending on temperature of testing as mold hardness increased from 60 to 90 or above. When the ramming energy is held constant, maximum hot compressive strength is reached at about 6 per cent western or southern bentonite. Below these percentages, hot compressive strength increases with increasing bentonite content. Above the same percentages, increasing bentonite content lowers hot compressive strength. Fire clay does not display an optimum clay content for maximum hot compressive strength as do the bentonites. Instead, hot compressive strength increases continually with increasing fire clay content until the maximum hot compressive strength characteristic of fire clay itself is reached.

Iron foundry sands containing carbonaceous additives have much lower hot strength than equivalent simple sand-clay mixtures. The role of additives requires further study. The actual hot compressive strength necessary for producing castings of various sizes remains to be determined.

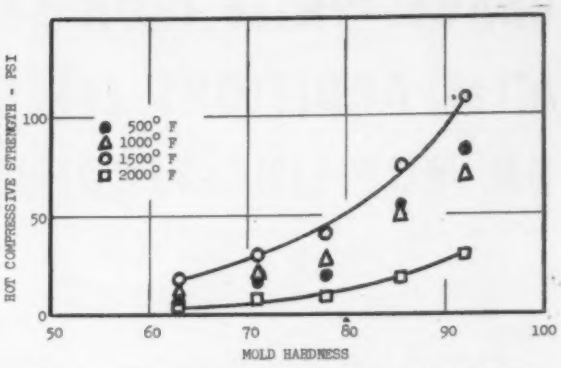

Fig. 14 — Hot compressive strength — mold hardness relationship for an actual foundry molding sand bonded with western bentonite.

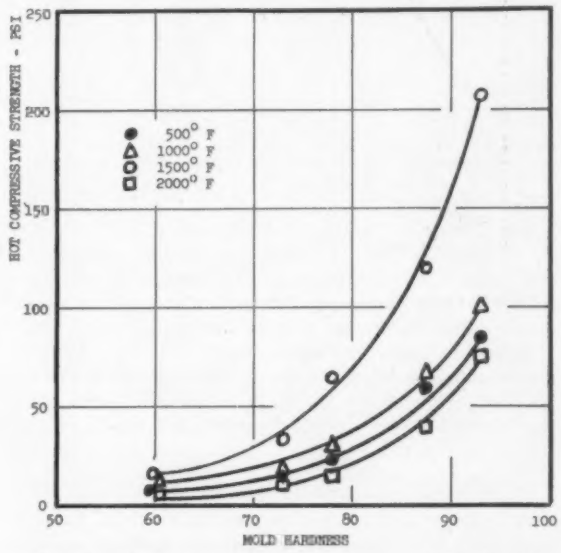

Fig. 15 — Hot compressive strength — mold hardness relationship for an actual foundry molding sand bonded with southern bentonite.

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HEAVY WHITE IRON SECTIONS MELT ADDITIONS EFFECTS ON MOTTLING TENDENCY

Progress Report
Malleable Division
Sponsored by
AFS Training & Research Institute

by C. R. Loper, Jr. and R. W. Heine

Part I

ABSTRACT

This second annual progress report, under the direction of the AFS Malleable Div., and sponsored by the AFS Training & Research Institute, summarizes research aimed at producing heavy section iron castings without mottling or primary graphitization during freezing, while having sufficient graphitizing tendency in the solid state so it may be malleablized by heat treatment. This report presents further research on the effect of various additions on mottling tendency of the 4 x 4 x 8 in. casting, the 1⅞-in. diameter bar and the 1⅜-in. diameter bar. Some of the additions used are bismuth, tellurium, thallium, indium and zinc.

INTRODUCTION

This report summarizes results of research work aimed at producing heavy section castings from an iron of such composition and/or melting practice that mottling or primary graphitization will not occur during the freezing of the casting, and that has sufficient graphitizing tendency in the solid state so that it may be malleablized by a commercially feasible heat treatment. This is the second annual progress report presented on this project sponsored at University of Wisconsin by the AFS Training & Research Institute under the direction of the AFS Malleable Div.

The previous report[1] presented:

1) A literature survey of the problem, including a discussion of the various criteria, relating chemical composition and section size to mottling tendency.
2) The experimental procedure which was followed, including the melting and casting procedure, the furnace atmosphere used during melting and the method of making additions to the melt.
3) The results of the experimental work, including the establishment of a base line representing the maximum carbon and silicon contents which will permit a white fracture in the 4 x 4 x 8 in. casting under the specified procedure. The effect of bismuth additions on this base line was also presented.

This report will present an extension of the work on the effect of various additions on the mottling tendency of the 4 x 4 x 8 in. casting, the 1⅞-in. diameter bar and the 1⅜-in. diameter bar.

ADDITIONS AND THEIR EFFECTS

Carbon and Silicon Effect

The effect of carbon and silicon on the mottling tendency of a 4 x 4 x 8 in. casting, a 1⅞-in. diameter bar and a 1⅜-in. diameter bar is shown in Figs. 1, 2 and 3, respectively. Data for these curves are presented in Table 1.

Figure 1 presents the maximum carbon and silicon content which will produce a 100 per cent visually white fracture, and the minimum carbon and silicon content which will produce a visually fully gray fracture in the 4 x 4 x 8 in. casting when melted under conditions standardized for this work. Also presented in Fig. 1, is the line representing the commonly accepted value of the maximum solubility of carbon in austenite alloyed with silicon. As the silicon content increases, the per cent of carbon separating white from gray fractures decreases. When a silicon percentage of about 2.5 is reached, the mottled zone between gray and white fractures becomes minimized. A small increase in carbon content across the curve, in the area of greater than 2.5 per cent silicon, results in a change from a 100 per cent white to a fully gray fracture in the 4 x 4 x 8 in. casting.

Both the white and gray "base line" curves appear to be asymptotic to the curve representing the maximum solubility of carbon in austenite alloyed with silicon.

Figure 2 presents the maximum carbon and silicon content which will produce a 100 per cent

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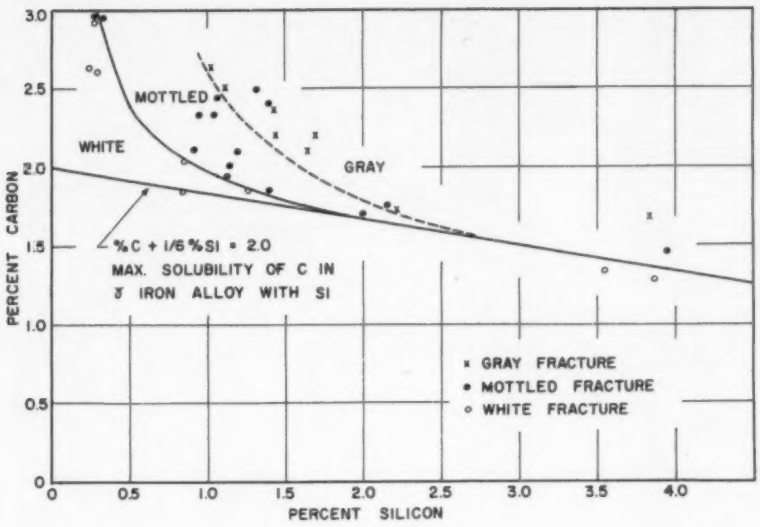

Fig. 1 — Carbon and silicon content effect on mottling tendency of the 4 x 4 x 8 in. casting, showing the maximum carbon and silicon percentages which will yield a fully white fracture and the minimum carbon and silicon percentages which will yield a completely gray fracture.

visually white fracture (white base line) for the 1⅞-in. diameter x 9 in. long bar. As is to be expected, higher carbon and silicon contents may be used to obtain a fully white fracture in the 1⅞-in. diameter bar than in the 4 x 4 x 8 in. casting. The white base line for the 1⅞-in. diameter bar also appears to be asymptotic to the curve of maximum solubility of carbon in austenite alloyed with silicon.

The effect of carbon and silicon content on the mottling tendency of the 1⅜-in. diameter x 6 in. long bar is shown in Fig. 3. The curve shown represents the maximum carbon and silicon percentages which produced fully white fractures in the 1⅜-in. diameter bar, and coincides with the white base line curve for the 1⅞-in. diameter bar. However, two instances of white fractures were also obtained at higher carbon and silicon contents, as noted in Fig. 3.

Bismuth Additions Effect

The effect of a 0.01 per cent bismuth addition at a metal temperature of 2750 F on the white base line curve for the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar is presented in Figs. 4 and 5, respectively. The data for these curves are presented in Table 2. The carbon and silicon contents used in this work were not high enough to obtain sufficient mottling data for evaluation of the 1⅜-in. diameter bar. The effect of this bismuth addition is greater at low silicon contents for both the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar. Beyond about 2.4 per cent silicon, the 0.01 per cent bismuth addition has little effect on the ability to obtain a fully white fracture in either the 4 x 4 x 8 in. casting or the 1⅞-in. diameter bar.

The effect of bismuth additions other than 0.01 per cent on the fractures obtained are presented

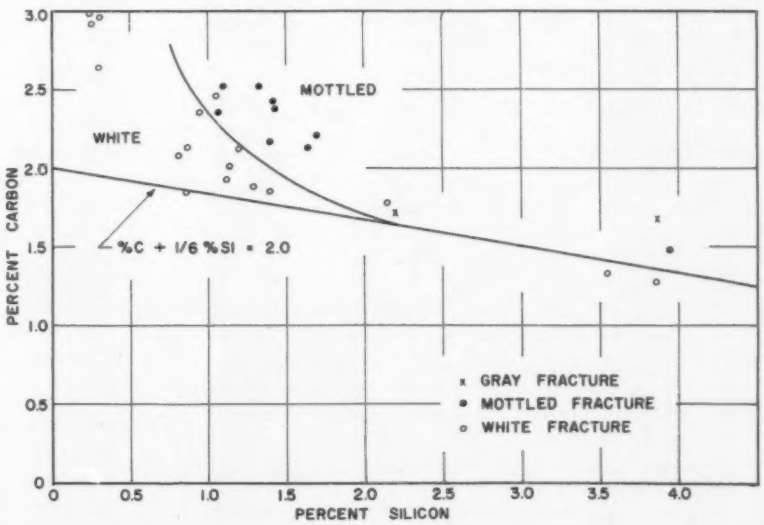

Fig. 2 — Carbon and silicon content effect on the mottling tendency of the 1⅞-in. diameter bar, showing the maximum carbon and silicon percentages which will yield a fully white fracture.

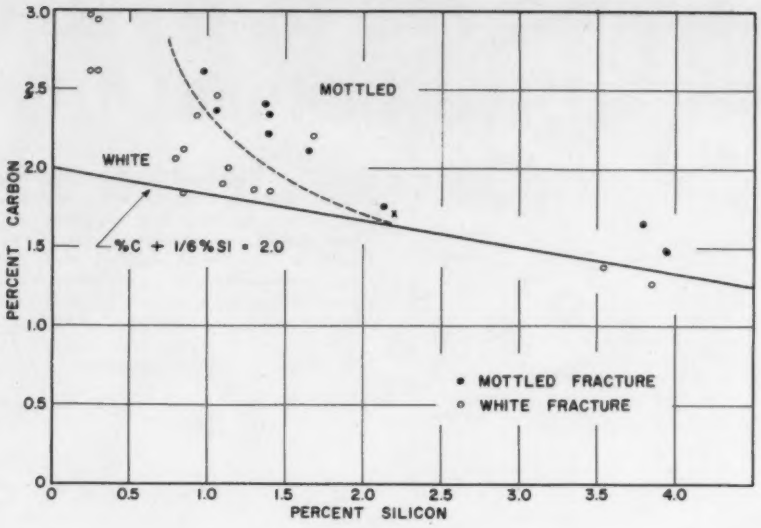

Fig. 3 — Carbon and silicon content effect on the mottling tendency of the 1⅜-in. diameter bar.

in Figs. 6 and 7 for the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar, respectively. Data for these curves are presented in Table 3. Bismuth additions greater than 0.01 per cent are noted to have no effect on either raising or lowering the white base line curve for both the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar. However, as the bismuth addition was increased above 0.01 per cent, dark spots appeared in what should have been a white fracture.

As the size of the bismuth addition was increased up to 0.345 per cent, these holes became larger. Metallographic examination revealed these spots to be gas and/or shrinkage cavities. Gas cavities may be expected from high bismuth additions since the excess is evolved as a vapor, the boiling point of bismuth being 2642 F.[2]

The effect of bismuth additions of less than 0.01 per cent is also presented in Figs. 6 and 7. Data for these points are presented in Table 3. In heat A14, 2.10 per cent C and 1.40 per cent Si, a fully white fracture in the 4 x 4 x 8 in. casting is obtained with the addition of 0.005 per cent Bi. At a similar composition, heat A89 was lightly mottled with the addition of 0.004 per cent Bi. The same effect was obtained in the 1⅞-in. diameter bar. In this composition range, a bismuth addition of 0.005 per cent is as effective as a bismuth addition of 0.01 per cent insofar as obtaining a white fracture is concerned.

TABLE 1 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — NO ADDITIONS MADE

Chemical Analysis[1]			Fracture Results[2]		
Heat No.	C, %	Si, %	4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
1	2.50*	1.09*	G	HM	—
2	2.50*	1.32*	M	LM	—
8	2.39*	1.40*	G	M	M
11	2.44*	1.07*	LM	W	W
12	2.34*	1.05*	M	LM	LM
13	2.20*	1.41*	G	M	M
14	2.12*	1.21*	M	W	W
15	1.85	0.86	W	W	W
16	2.34*	0.95*	M	W	W
17	2.05*	0.82*	W	W	W
18	2.10	0.86	M	W	W
19	1.90*	1.12*	LM	W	W
20	2.00	1.15	M	W	W
21	1.85*	1.40*	LM	W	W
22	2.94*	0.30*	M	W	W
23	2.60*	0.30*	W	W	W
24	1.66*	3.85*	G	HM	HM
25	3.03*	0.25*	LM	W	W
26	1.26*	3.86*	W	W	W
27	1.32*	3.55*	W	W	W
28	1.63	2.00	HM	—	—
29	1.45*	3.96*	HM	HM	HM
30	2.60*	0.26*	W	—	W
31	2.92*	0.27*	W	W	—
54	2.11	1.65	G	M	LM
55	2.20*	1.70*	G	M	W
81	1.87*	1.28*	W	W	W
82	1.76*	2.14*	HM	LM	LM
83	1.72*	2.20*	G	G	G
A5	2.60	0.99	G	—	LM
A53	2.40	1.40	LM	LM	LM

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

Addition Temperature Effect

Table 3 presents those heats to which bismuth was added at temperatures differing from the normal procedure. A reference[1] cites that when bismuth was added to the melt at 2600 F and the castings poured at 2600 F, the effect on the mottling tendency was the same as if bismuth had not been added at all. The standard procedure is to add bismuth at 2750 F and pour at 2700 F. When bismuth additions were made at 2750 F, a considerable amount of fuming was evident. On the other hand, the addition of bismuth of 2600 F was accompanied by no evolution of fumes. This is again related to the 2642 F boiling point of bismuth.

Bismuth Compounds Effect

The effect of adding bismuth in the form of bismuth compounds was also studied. Table 12 shows data obtained when bismuth was added as Bi_2O_3 (heat 80), $BiCl_3 \cdot 2H_2O$ (heat A36), BiOCl (heat A51)

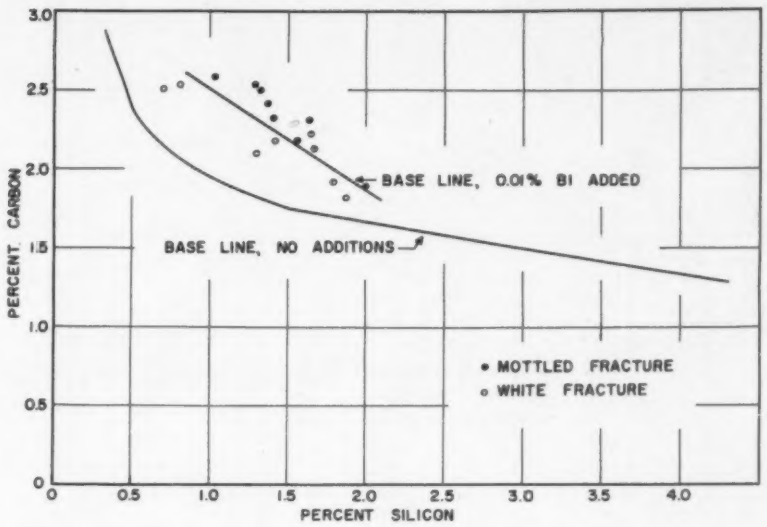

Fig. 4 — Effect of 0.01 per cent bismuth added on the base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 4 x 4 x 8 in. casting.

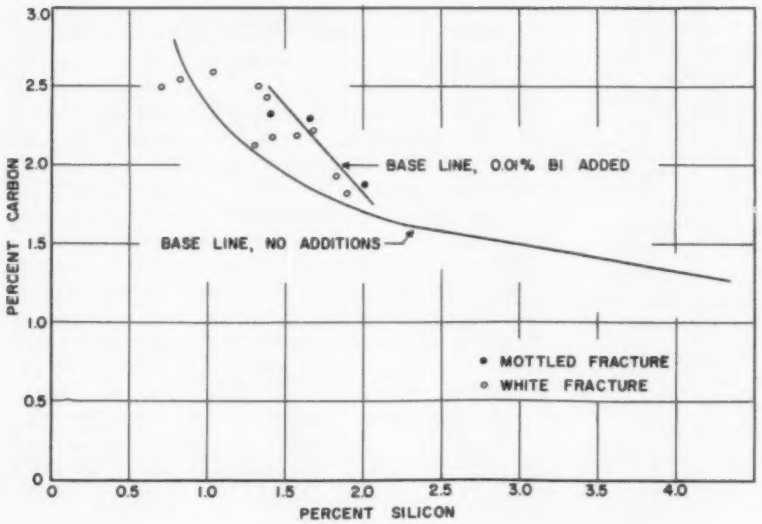

Fig. 5 — Effect of 0.01 per cent bismuth added on the base curve or maximum carbon and silicon percentages which will yield a fully white fracture in the 1⅞-in. diameter bar.

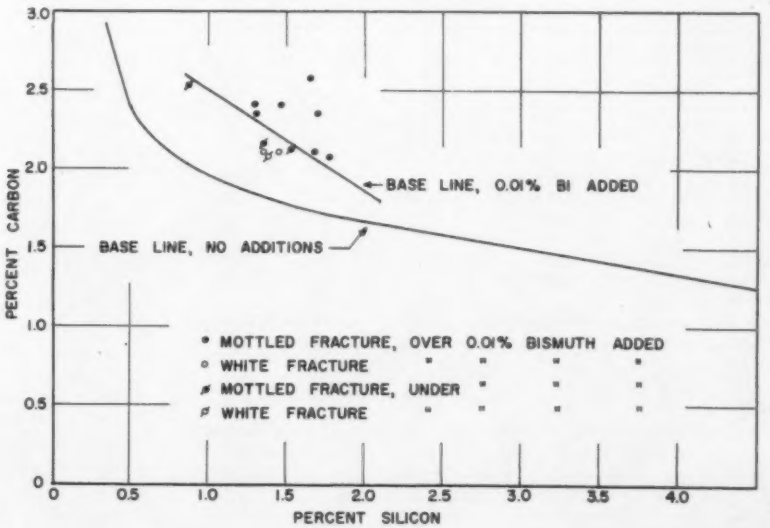
PERCENT CARBON
PERCENT SILICON
BASE LINE, 0.01% BI ADDED
BASE LINE, NO ADDITIONS
• MOTTLED FRACTURE, OVER 0.01% BISMUTH ADDED
○ WHITE FRACTURE " " " "
MOTTLED FRACTURE, UNDER " " " "
WHITE FRACTURE " " " "

Fig. 6 — Miscellaneous bismuth additions effect on the 0.01 per cent bismuth added base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 4 x 4 x 8 in. casting.

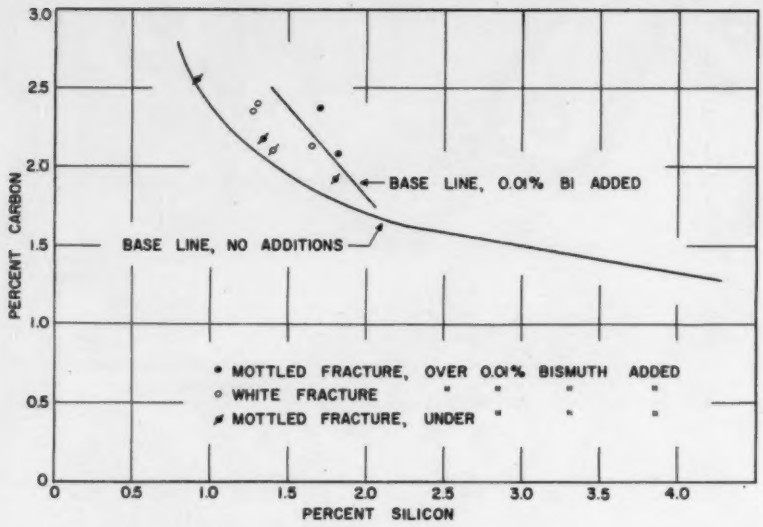

Fig. 7 — Miscellaneous bismuth additions effect on the 0.01 per cent bismuth added base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 1⅞-in. diameter bar.

and $Bi(NO_3)_3 \cdot 5H_2O$ (heat A52). In all four instances the results obtained were comparable to those obtained with the 0.01 per cent bismuth additions. Due to there being no really effective method of analyzing for small quantities of bismuth, the effect of adding bismuth in the form of bismuth compounds on the recovery could not be determined.

Water Vapor Effect

The effect of an addition of 12 grains of water vapor/cu ft of gas over the melt in the furnace on the mottling tendency of the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar is shown in Figs. 8 and 9, respectively. The data for these curves are presented in Table 4.

Comparison of Figs. 4 (0.01 per cent Bi added) and 8 (12 grains water vapor) shows that 12 grains of water vapor is not as effective as an addition of 0.01 per cent bismuth in raising the base line for the 4 x 4 x 8 in. casting, especially for irons of lower silicon content.

TABLE 2 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — 0.01 PER CENT BISMUTH ADDED

Heat No.	Chemical Analysis[1] C, %	Si, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
3	2.50*	1.33*	M	W	W
6	2.42*	1.39*	M	W	W
33	1.88*	2.00*	M	M	—
34	2.18*	1.41*	W	W	W
35	2.59*	1.03*	M	W	W
36	1.94*	1.82*	W	W	W
37	2.11	1.30	W	W	W
38	2.50	0.70	W	W	W
39	1.83*	1.89*	W	W	W
40	2.18*	1.57*	LM	W	W
41	2.55*	0.82*	W	W	W
60	2.11	1.65	W	—	W
66	2.24*	1.66*	W	W	W
84	2.30	1.65	HM	HM	LM
A83	2.51	1.32	LM	W	W

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses have been obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

For the 1⅞-in. diameter bar (Fig. 9) the effect of the water vapor addition is that water vapor is less effective in moving the base line at lower silicon contents than at higher silicon contents.

Data showing the effect of 25 grains of water vapor/cu ft of gas in the atmosphere over the melt on the mottling tendency of the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar are presented in Table 5 and plotted in Figs. 8 and 9, respectively. The increase in water vapor addition from 12 to 25 grains/cu ft does not appreciably alter the position of the base line.

TABLE 3 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED—MISCELLANEOUS BISMUTH ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Bi Added, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
4	2.40*	1.30*	0.02	M	W	W
5	2.36*	1.28*	0.05	M	W	W
7	2.40*	1.49*	0.10	M	—	W
9[3]	2.34*	1.42*	0.01	M	M	M
10[3]	2.41*	1.41*	0.10	HM	W	W
42	2.11	1.65	0.05	LM	W	—
52	2.34*	1.68*	0.05	M	W	W
67[4]	2.30	1.65	0.01	G	G	—
68[4]	2.58	1.65	0.05	G	G	M
69	2.58	1.65	0.05	M	—	—
70[4]	2.58	1.65	0.05	G	—	—
85[5]	2.30*	1.67*	0.01	LM	W	W
A13	2.10	1.40	0.05	W	—	W
A14	2.10	1.40	0.005	W	—	—
A16	2.12*	1.52*	0.0025	LM	—	—
A18	2.10*	1.43*	0.10	W	—	—
A59	2.10	1.40	0.20	W	W	W
A61	2.10	1.40	0.345	W	W	W
A88	2.51	0.89	0.004	LM	LM	W
A89	2.17	1.42	0.004	LM	W	W
A92	1.92	1.80	0.004	HM	LM	W

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses have been obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.
3. Bismuth added at 2700 F, poured at 2680 F.
4. Bismuth added at 2600 F, poured at 2600 F.
5. Bismuth added at 2700 F, poured at 2600 F.

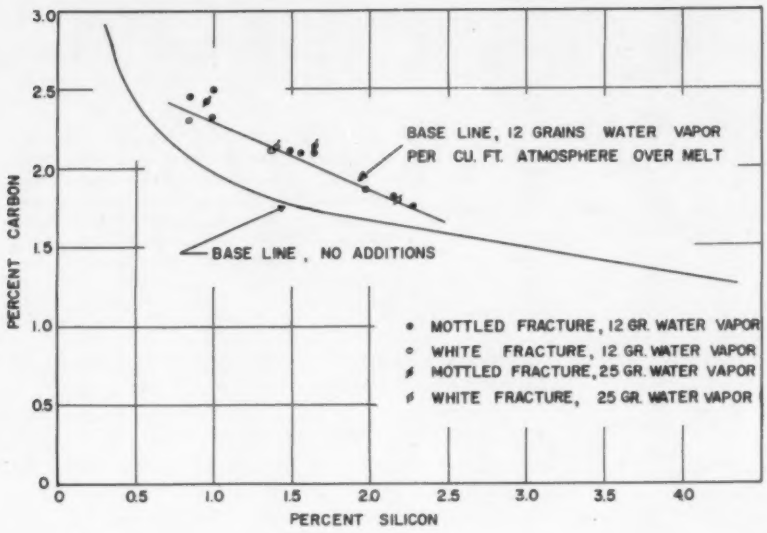
PERCENT CARBON
PERCENT SILICON
BASE LINE, 12 GRAINS WATER VAPOR PER CU. FT. ATMOSPHERE OVER MELT
BASE LINE, NO ADDITIONS
MOTTLED FRACTURE, 12 GR. WATER VAPOR
WHITE FRACTURE, 12 GR. WATER VAPOR
MOTTLED FRACTURE, 25 GR. WATER VAPOR
WHITE FRACTURE, 25 GR. WATER VAPOR

Fig. 8 — Water vapor additions to the atmosphere over the melt effect on the maximum carbon and silicon percentages which will yield a fully white fracture in the 4 x 4 x 8 in. casting.

Tellurium Additions Effect

Base lines showing the mottling tendency of the 4 x 4 x 8 in. casting when 0.01 per cent tellurium is added according to the prescribed procedure are presented in Fig. 10. The data for these curves are presented in Table 6. The shift in the base curve representing maximum carbon and silicon contents that will produce a fully white fracture is greater for the 0.01 per cent tellurium additions than for any of the additions studied to date. An estimated curve representing the effect of 0.01 per cent tellurium additions on the gray base line is also presented. As with the bismuth and water vapor additions, the effect is greater at lower silicon contents.

Figure 11 presents the base line curve for the effect of the addition of 0.01 per cent tellurium on the mottling tendency of the 1⅞-in. diameter bar. The data for this curve are also presented in Table 6.

Figures 12 and 13 present the effect of additions of

TABLE 4 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — 12 GRAINS WATER VAPOR ADDED/CU FT OF GAS IN ATMOSPHERE OVER THE MELT

Chemical Analysis[1]			Fracture Results[2]		
Heat No.	C, %	Si, %	4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
43	2.10*	1.63*	M	W	W
A40	2.10	1.55	LM	W	W
A41	2.50	1.00	M	LM	W
A42	1.88*	1.98*	W	W	W
A43	2.12*	1.49*	M	LM	W
A44	2.32*	0.99*	LM	LM	W
A45	1.82*	2.15*	LM	W	W
A46	2.12*	1.36*	W	W	W
A47	2.46*	0.86*	LM	LM	W
A54	2.30*	0.84*	W	W	W
A58	1.76*	2.27*	LM	W	W

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

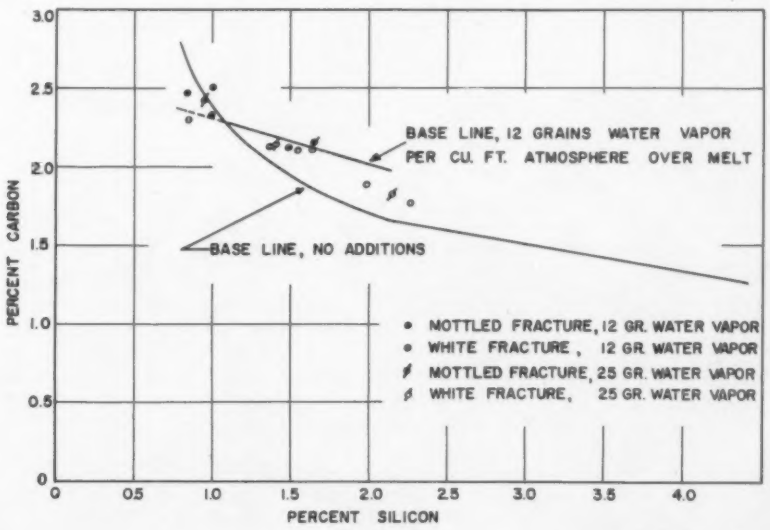
PERCENT CARBON
PERCENT SILICON
BASE LINE, 12 GRAINS WATER VAPOR PER CU. FT. ATMOSPHERE OVER MELT
BASE LINE, NO ADDITIONS
MOTTLED FRACTURE, 12 GR. WATER VAPOR
WHITE FRACTURE, 12 GR. WATER VAPOR
MOTTLED FRACTURE, 25 GR. WATER VAPOR
WHITE FRACTURE, 25 GR. WATER VAPOR

Fig. 9 — Water vapor additions to the atmosphere over the melt effect on the maximum carbon and silicon percentages which will yield a fully white fracture in the 1⅞-in. diameter bar.

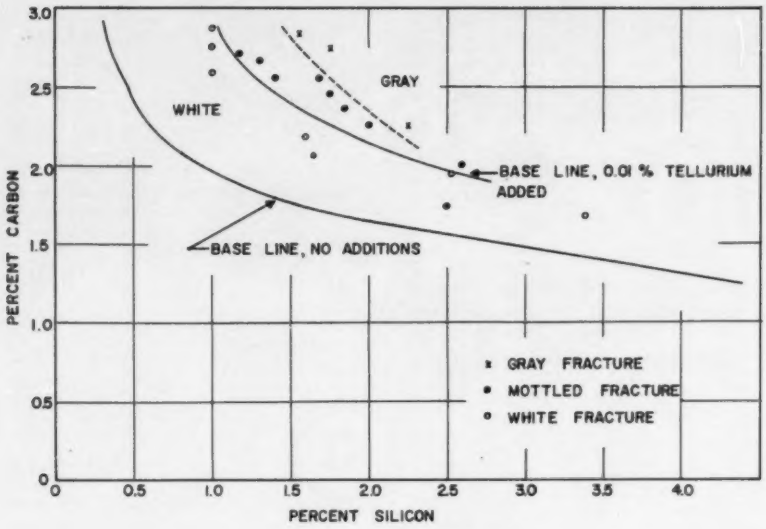

Fig. 10 — Effect of 0.01 per cent tellurium added on the base curve of maximum carbon and silicon percentages which will yield a fully white fracture and the minimum carbon and silicon percentages which will yield a completely gray fracture in the 4 x 4 x 8 in. casting.

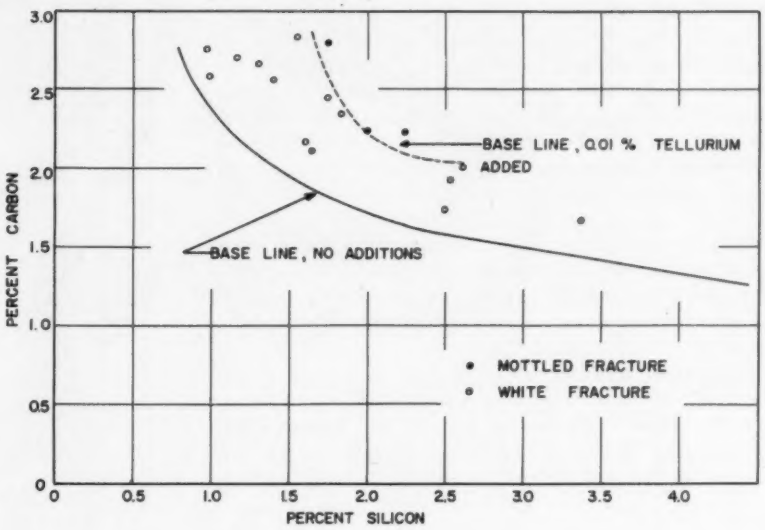

Fig. 11 — Effect of 0.01 per cent tellurium added on the base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 1⅞-in. diameter bar.

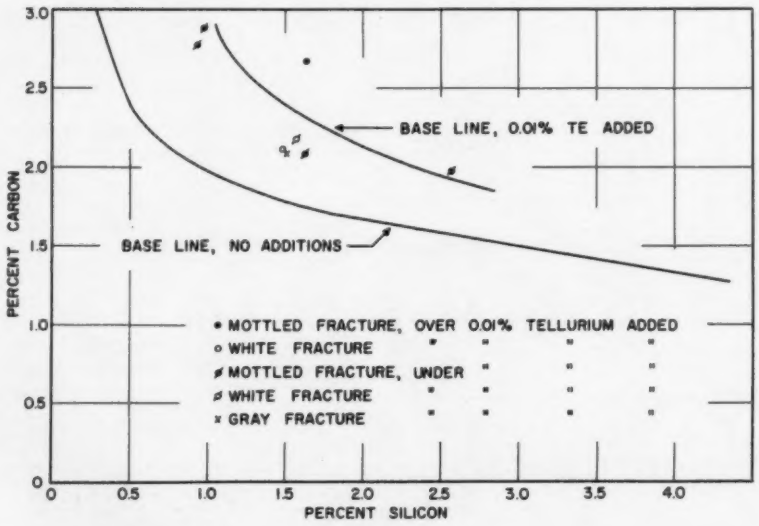

Fig. 12 — Miscellaneous tellurium additions effect on the 0.01 per cent tellurium added base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 4 x 4 x 8 in. casting.

TABLE 5 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — 25 GRAINS WATER VAPOR ADDED/CU FT OF GAS IN ATMOSPHERE OVER THE MELT

Heat No.	Chemical Analysis[1] C, %	Si, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
47	2.14*	1.40*	W	W	W
A64	2.42*	0.95*	HM	LM	W
A65	2.14*	1.65*	HM	LM	LM
A66	1.82	2.15	W	W	W

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

tellurium of other than 0.01 per cent on the mottling tendency of the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar, respectively. The data for these curves are presented in Table 7. Heat A86 (2.18 per cent C and 1.59 per cent Si) was white in both the 4 x 4 x 8 in. casting and the 1⅞-in. diameter bar with the addition of 0.004 per cent Te. Heat A15 of similar composition was lightly mottled in the 4 x 4 x 8 in. casting with an addition of 0.0027 per cent Te. In this composition range, it appears that a tellurium addition of 0.004 per cent is as effective as a tellurium addition of 0.01 per cent in obtaining a white fracture in the 4 x 4 x 8 in. casting. Additions of tellurium greater than 0.01 per cent were not effective in altering the base line obtained from a 0.01 per cent tellurium addition.

Thallium Additions Effect

The chemical analyses and fracture results of heats poured containing thallium additions are presented in Table 8. The effect of 0.009 to 0.01 per cent thallium added on the mottling tendency of the 4 x 4 x 8 in. casting is shown in Fig. 14, and of the 1⅞-in. diameter bar is shown in Fig. 15.

A base line has not been drawn in Fig. 14 for the 4 x 4 x 8 in. casting, since the location of the white-mottled line is indefinite. However, the data for the

TABLE 6 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — 0.01 PER CENT TELLURIUM ADDED

Heat No.	Chemical Analysis[1] C, %	Si, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
65	2.19*	1.61*	W	W	W
86	2.82*	1.75*	G	HM	—
87	2.25	2.25	G	LM	—
88	1.75	2.50	W	W	W
89	2.02*	2.61*	LM	W	W
90	2.25	2.00	HM	LM	W
91	2.85*	1.56*	G	M	—
93	2.89*	0.98*	W	—	—
94	1.94*	2.53*	W	W	W
95	2.68	1.30	HM	W	W
96	2.46*	1.75*	LM	W	W
97	2.73*	1.17*	LM	W	W
98	2.36*	1.85*	HM	W	W
A6	2.77	0.99	W	W	W
A7	2.57	1.40	LM	W	W
A8	2.60	0.99	W	W	W
A9	1.68*	3.38*	W	W	W
A69	2.56*	1.69*	M	W	—

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

TABLE 7 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED—MISCELLANEOUS TELLURIUM ADDED

Heat No.	Chemical Analysis[1] C, %	Si, %	Te Added, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
51	2.11	1.65	0.05	W	W	W
A15	2.08*	1.62*	0.0027	LM	—	W
A17	2.10	1.50	0.0014	G	—	—
A19	2.10	1.50	0.137	W	—	W
A85	2.86	0.99	0.004	LM	W	W
A86	2.18	1.59	0.004	W	W	W
A87	1.98	2.52	0.004	HM	W	W
A93	2.68	1.62	0.10	M	W	W
A97	2.78	0.96	0.002	M	—	—

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

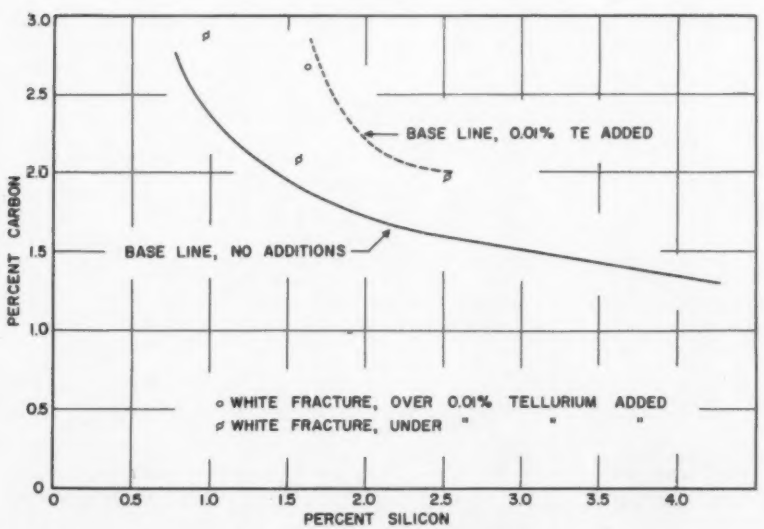

Fig. 13 — Miscellaneous tellurium additions effect on the 0.01 per cent tellurium added base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 1⅞-in. diameter bar.

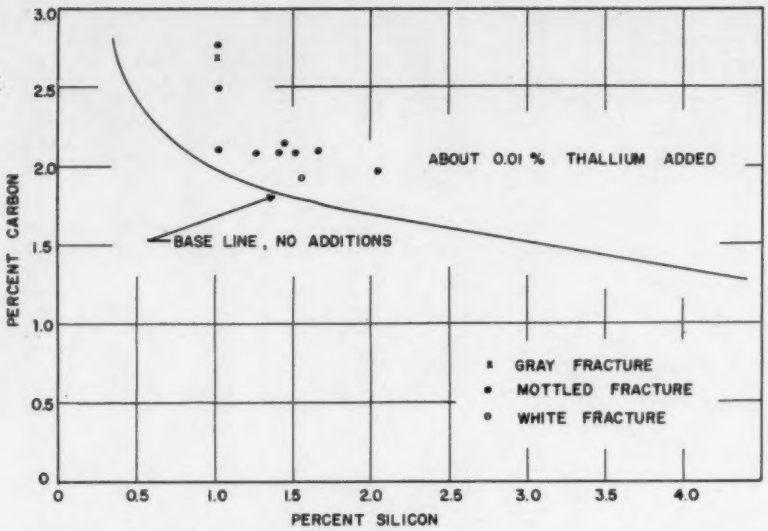

Fig. 14 — Effect of 0.01 per cent thallium added on the base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 4 x 4 x 8 in. casting.

TABLE 8 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED— THALLIUM ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Tl Added, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1¼-in. D. Bar
78	2.11	1.65	0.009	HM	W	—
99	2.77	1.01	0.009	M	LM	—
A	1.98	2.03	0.01	HM	W	W
A1	2.10	1.50	0.009	HM	W	W
A2	2.50	1.01	0.01	HM	LM	—
A3	1.93*	1.55*	0.009	W	W	W
A4	2.12*	1.01*	0.009	LM	W	W
A20	2.10	1.40	0.0025	HM	LM	W
A21	2.10	1.40	0.005	HM	LM	W
A22	2.10	1.40	0.01	HM	LM	W
A23	2.10	1.40	0.05	HM	LM	W
A33	2.70	1.01	0.009	G	HM	M
A34	2.10	1.25	0.009	LM	W	W
A60[3]	2.16*	1.43*	0.01	LM	W	W
A72[3]	2.11	1.65	0.01	G	M	LM

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.
3. Thallium added at 2675 F, poured at 2625 F.

1⅞-in. diameter bar (plotted in Fig. 15) allow a base line to be approximated.

The effect of variation in the amount of thallium added on the base line is shown from the results of four heats in Table 7. Varying the amount of thallium; 0.0025 per cent (heat A20), 0.005 per cent (heat A21), 0.01 per cent (heat A22) and 0.05 per cent (heat A23); in a 2.10 per cent C, 1.40 per cent Si iron did not appreciably change the fracture obtained. In all of these instances the 4 x 4 x 8 in. casting had a heavily mottled fracture.

A definite effect due to temperature of addition was noted, however. When 0.01 per cent thallium was added to a 2.16 per cent C, 1.43 per cent Si iron (heat A60, Table 7) at 2675 F and poured at 2625 F, the 4 x 4 x 8 in. casting produced a lightly mottled fracture. This is in contrast to heats A1 and A22 of similar composition where about 0.01 per cent thallium was added at 2750 F and poured at 2700 F producing a heavily mottled fracture.

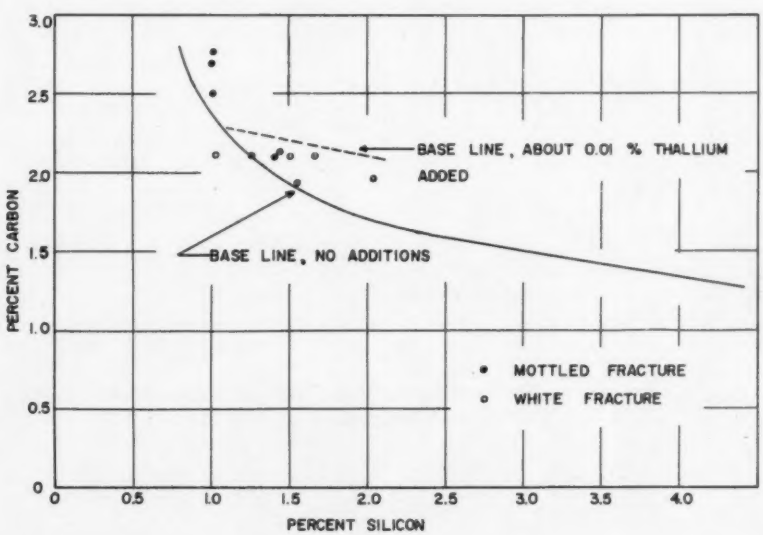

Fig. 15 — Effect of 0.01 per cent thallium added on the base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 1⅞-in. diameter bar.

TABLE 9 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — INDIUM ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	In Added, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
72	2.11	1.65	0.007[3]	W	—	W
A10	2.50	1.22	0.01	G	—	—
A11	2.10	1.75	0.01	G	—	—
A12	1.78	2.30	0.01	HM	—	—
A24	2.10	1.40	0.0025	HM	LM	W
A25	2.10	1.40	0.005	HM	LM	W
A26	2.10	1.40	0.0075	HM	LM	W
A27	2.10	1.40	0.01	HM	M	W
A29	2.10	1.65	0.007	G	M	LM

1. Estimated chemical analysis.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.
3. Indium added to this heat was produced in the 1940's, whereas all other indium additions were of high purity indium.

Indium Additions Effect

Table 9 contains chemical analyses and fracture results of heats poured containing indium additions. With the exception of heat 72, which was white, all fracture results are similar to that expected when no additions were made. However, high purity indium was added to all heats except heat 72, to which indium produced in the early 1940's was added. The properties of indium from the 1940's were considerably different from present day sources, due to impurities, etc. For instance, the boiling point recorded for 1940 indium was 2642 F while that for present day indium is 3632 F.

Variation of the amount of indium added to values less than 0.01 per cent did not assist in obtaining a fully white fracture.

Zinc Additions Effect

The effect of additions of zinc as the element and in compounds is presented in Table 10. An anomalous behavior of the zinc addition may be noted by comparing heat 53, reported to be white in the 4 x 4 x 8 in. casting when 0.01 per cent Zn was added, heats 56 and 57 where a 0.01 per cent Zn addition to the same analyses resulted in a gray fracture, and heat 49 to which 0.05 per cent Zn was added to the same analysis causing a mottled fracture.

Repeating the above heats with an alloy of lower silicon and with smaller and larger amounts of zinc added, heats A31 and A32, respectively, did not materially change the results.

With the exception of heat A37 where zinc was added as ZnS, zinc when added as a compound (Table 10) ($ZnSO_4 \cdot 7H_2O$, heat A49 or $ZnCl_2$, heats A38, A48, A55 and A56) produced a lightly mottled fracture in the 4 x 4 x 8 in. casting where a heavily mottled fracture would be expected from the addition of zinc as the element.

Addition of Other Elements Effect

The effect of other elements on either raising or lowering the base line curve was studied. Table 11 presents the fracture results and chemical analysis of those additions used.

The effect on raising the base line was studied at 2.11 per cent C and 1.65 per cent Si. With the exception of heat 64 to which 0.01 per cent Se was added resulting in a mottled fracture, all of the elements added produced either a heavily mottled or gray fracture as expected with no additions. The amount of the element added was as follows: 0.024 per cent, 0.061 per cent and 0.117 per cent cerium (heats 77, 92, and A39, respectively), 0.05 per cent selenium (heat 61), 0.01 per cent arsenic (heat 44), 0.01 per cent antimony (heat 45), 0.05 per cent tin (heat 48), 0.05 per cent lead (heat 50), 0.01 per cent calcium (heat 58) and 0.01 per cent magnesium (heat 62).

The effect on lowering the base line was studied at 2.00 per cent C and 0.72 per cent Si for additions of

TABLE 10 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — ZINC AND ZINC COMPOUND ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Addition, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
49	2.11	1.65	0.5 Zn	M	—	—
53	2.11	1.65	0.01 Zn	W	W	—
56	2.11	1.65	0.01 Zn	G	M	—
57	2.11	1.65	0.01 Zn	G	M	—
A31	2.10	1.40	0.005 Zn	HM	LM	W
A32	2.10	1.40	0.10 Zn	HM	M	W
A37	2.10	1.40	0.01 Zn as ZnS	HM	LM	M
A38	2.10	1.40	0.01 Zn as $ZnCl_2$[3]	LM	LM	W
A48	2.10	1.40	0.01 Zn as $ZnCl_2$	LM	LM	W
A49	2.10	1.40	0.01 Zn as $ZnSO_4 \cdot 7H_2O$	LM	W	W
A55	2.10	1.30	0.01 Zn as $ZnCl_2$	LM	LM	W
A56	2.16*	1.23*	0.01 Zn as $ZnCl_2$	LM	W	W

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.
3. $ZnCl_2$ used in this heat had picked up considerable water from the atmosphere before it was added.

TABLE 11 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — MISCELLANEOUS ELEMENTS ADDED

Heat No.	Chemical Analysis[1] C, %	Si, %	Additions, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
A28	1.83	1.20	0.151 Al	HM	LM	LM
A35	1.80*	1.32*	0.137 Al	M	M	M
N3	2.00	0.79	0.013 Al	W	W	W
77	2.11	1.65	0.024 Cs	G	G	M
92	2.11	1.65	0.061 Cs	G	G	G
A39	2.10	1.65	0.117 Ce	G	G	LM
61	2.11	1.65	0.05 Se	G	M	—
64	2.11	1.65	0.01 Se	M	M	—
44	2.11	1.65	0.01 As	G	M	—
45	2.11	1.65	0.01 Sb	G	M	—
48	2.11	1.65	0.05 Sn	G	G	—
50	2.11	1.65	0.05 Pb	HM	G	—
58	2.11	1.65	0.01 Ca	G	HM	M
62	2.11	1.65	0.01 Mg	G	W	W
A94	2.00	0.79	0.01 Ca	W	W	W
A98	2.00	0.79	0.01 As	W	W	W
A99	2.00	0.79	0.01 Sb	W	W	W
N	2.00	0.79	0.01 Sn	W	W	W
N1	2.00	0.79	0.01 Mg	W	W	W
N2	2.00	0.79	0.01 Ti as Fe-Ti	W	W	W

1. Estimated chemical analyses unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

TABLE 12 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — MISCELLANEOUS CHEMICAL COMPOUNDS ADDED[1]

Heat No.	Chemical Analysis[2] C, %	Si, %	Additions, %	Fracture Results[3] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
80	2.11	1.65	0.02 Bi as Bi_2O_3	LM	W	—
A36	2.10	1.40	0.01 Bi as $BiCl_3 \cdot H_2O$	W	W	W
A51	2.10	1.40	0.01 Bi as BiOCl	W	W	W
A52	2.10	1.40	0.01 Bi as $Bi(NO_3)_3 \cdot 5H_2O$	W	W	W
A70	2.11	1.30	0.01 Bi as Mg as $MgCl_2$	HM	LM	W
A73	2.11	1.40	0.04 Mg as $MgCl_2$	M	M	LM
74	2.11	1.65	0.01 Na as NaCl	G	M	—
A57	2.11	1.40	0.01 Na as $NaBO_2 \cdot 4H_2O$	M	LM	W
59	2.11	1.65	0.0085 Sr as SrO	M	—	M
63	2.11	1.65	0.043 Sr as SrO	M	M	M
A50	2.10	1.40	0.01 Sr as SrO	M	LM	W
76	2.11	1.65	0.01 K asKI	M	M	—
79	2.11	1.65	0.01 K as KI	HM	LM	—
A30	2.10	1.65	0.01 K as KI	G	M	LM
71	2.11	1.65	0.02 Ba as $BaCl_2$	G	M	—
73	2.11	1.65	0.009 In as In_2O_3	G	M	—
75	2.11	1.65	0.005 Li as LiCl	G	M	—

1. Zinc compounds will be found in Table 10.
2. Estimated chemical analyses.
3. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

0.01 per cent arsenic (heat A98), 0.01 per cent antimony (heat A99), 0.01 per cent tin (heat N), 0.01 per cent magnesium (heat N1), 0.01 per cent titanium added as ferro-titanium (heat N2) and 0.013 per cent aluminum (heat N3). None of these additions caused primary graphitization at this analysis, and all of the fractures were fully white as expected from the base line curve for no additions. Hence, no graphite nucleating effect need be attributed to these elements at this composition.

However, the addition of 0.151 per cent aluminum at 1.83 per cent C and 1.20 per cent Si and 0.137 per cent aluminum at 1.80 per cent C and 1.32 per cent Si resulted in a heavily mottled and mottled fracture in the 4 x 4 x 8 in. casting, respectively. The 1⅞-in. diameter bar and the 1⅜-in. diameter bar were lightly mottled and mottled, respectively, as shown by the data in Table 11.

Addition of Other Compounds Effect

Table 12 presents the chemical analysis and fracture results of heats to which compounds other than Zn compounds have been added. The effect of the bismuth compounds listed in this table has been previously discussed.

Magnesium added as $MgCl_2$ to heats A70 and A73, sodium added as NaCl to heat 74 and as $NaBO_2 \cdot 4H_2O$ to heat A57, strontium added as SrO to heat A50, potassium added as KI to heats 76, 79 and A30, barium added as $BaCl_2$ to heat 71, indium added as In_2O_3 to heat 73 and lithium added as LiO to heat 75 resulted in fractures similar to those expected when no additions were made to irons of the same carbon and silicon contents.

However, in heats 59 and 63 where 0.0085 per cent Sr and 0.043 per cent Sr were added as SrO, respectively, the fracture of the 4 x 4 x 8 in. casting was, depending on the point of fracture, white for a depth of ¼ to ¾-in. from the surface, mottled for ½-in. below the white zone and gray in the center.

Combined Additions Effect

Table 13 presents a list of heats to which combinations of elements were added. Heat 46, of 2.12 per cent C and 1.36 per cent Si, to which 12 grains of water vapor/cu ft of gas in the atmosphere over the melt plus 0.01 per cent bismuth were added, resulted in a fracture similar to that obtained with either the water vapor or bismuth alone. The combination was not observed to raise the base line curve.

Combinations of 0.01 per cent bismuth plus 0.01 per cent tellurium (heats A67, A68 and A71) did not cause fracture results different from those obtained when only 0.01 per cent tellurium was added in either the 4 x 4 x 8 in. casting or the 1⅞-in. diameter bar. The addition of 0.002 per cent bismuth plus 0.002 per cent tellurium to heats A90 and A91 resulted in fractures similar to that expected from a low tellurium addition in the 4 x 4 x 8 in. casting. In the 1⅞-in. diameter bar, mottled and lightly mottled fractures for heats A90 and A91, respectively, were obtained where a white fracture was obtained with a 0.004 per cent tellurium addition. The combination of bismuth and tellurium did not appear to alter the effect obtained from a similar tellurium addition alone.

The addition of small amounts of bismuth in the form of a bismuth-lead alloy (heats A78 and A79) and in the form of a bismuth-indium alloy (heat A80)

TABLE 13 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEATS POURED — COMBINATION ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Combination Additions, %	Fracture Results[2] 4x4x8 in. Casting	1⅞-in. D. Bar	1⅜-in. D. Bar
46	2.12*	1.36*	0.01 Bi + 12 grains water vapor	M	LM	—
A67	2.56*	1.62*	0.01 Bi + 0.01 Te	LM	W	W
A68	2.40	1.19	0.01 Bi + 0.01 Te	W	W	W
A71	2.64	1.40	0.01 Bi + 0.01 Te	LM	W	W
A90	2.82	1.00	0.002 Bi + 0.002 Te	M	M	LM
A91	2.22	1.60	0.002 Bi + 0.002 Te	M	LM	—
A78	2.11	1.41	0.0025 Bi as 50 Bi — 50 Pb	LM	W	W
A79	2.11	1.41	0.00125 Bi as 50 Bi — 50 Pb	LM	W	W
A80	2.11	1.41	0.00125 Bi as 98.7 Bi — 1.3 In	LM	W	W
A81	2.51	1.32	0.15 Ti + 0.01 Bi	G	LM	W
A82	2.51	1.32	0.30 Cu + 0.01 Bi	LM	W	W
A84	2.51	1.32	0.30 Cu + 0.05 Bi	—	W	W
N4	2.66*	1.18*	0.01 Al + 0.01 Te	LM	W	W
N5	2.61*	1.20*	0.005 Al + 0.01 Te	LM	W	W
N6	2.65*	1.20*	0.055 Al + 0.01 Te	LM	W	W
N7	2.67*	1.22*	0.03 Al + 0.01 Te	W	W	W
N8	2.62*	1.56*	0.03 Al + 0.01 Te	M	LM	W
N9	2.59*	1.54*	0.03 Al + 0.01 Te	M	W	W
N10	2.66*	1.55*	0.03 Al + 0.02 Te	M	W	W
N11	2.20*	1.40	0.02 Al + 0.01 Zn as $ZnCl_2$	G	M	M
N13	2.55	1.55	0.005 Al + 0.01 Te + 0.003B	M	LM	W
N16	2.02	1.50	0.02 Al + 0.004 Te	LM	W	W

1. Estimated chemical analysis unless marked with an asterisk (*), for which actual chemical analyses were obtained.
2. G — gray; HM — heavily mottled, almost gray; M — mottled; LM — lightly mottled; W — 100 per cent white.

did not increase the effect of small amounts of bismuth on the base line. The effect produced was similar to that expected from the same addition of bismuth alone.

Addition of 0.30 per cent copper with 0.01 per cent bismuth (heat A82) also gave results similar to that expected from a 0.01 per cent bismuth addition. However, 0.15 per cent titanium added to heat A81 with 0.01 per cent bismuth caused a gray fracture where a white or lightly mottled fracture would be obtained with a 0.01 per cent bismuth addition.

TABLE 14 — DETERMINATION OF ALUMINUM RECOVERY

Heat No.	Al Added, %	Al Found, %
N4	0.01	0.005
N5	0.005	0.004
N6	0.055	0.025
N7	0.03	0.017
N8	0.03	0.020
N9	0.03	0.024
N10	0.03	0.022

1. Aluminum determination made by the spectrographic method.

The addition of aluminum and tellurium together was also studied. Data for these heats are presented in Table 13. Addition of 0.01 per cent tellurium and varying amounts of aluminum to irons of essentially the same composition (2.65 per cent C, 1.20 per cent Si) was made to heats N5 (0.005 per cent Al), N4 (0.01 per cent Al), N7 (0.03 per cent Al) and N6 (0.055 per cent Al). In this series of heats, the fractures of the 4 x 4 x 8 in. castings were — N5, lightly mottled; N4, less mottle than in N5, mottle spots are small and round; N7, white; and N6, fine mottle specks. The addition of 0.01 per cent tellurium alone at this composition would result in a lightly mottled fracture. As the aluminum addition increased to 0.03 per cent, the amount of mottling was decreased from a lightly mottled fracture to a fully white fracture. Addition of aluminum of more than 0.03 per cent, however, again resulted in mottle.

Two observations were made when the combination of aluminum and tellurium were added to the melt.

1) The addition of aluminum to the melt caused a scum to form over the melt which became thicker as the aluminum addition increased. An addition of 0.005 per cent Al was sufficient to cover only 50 per cent of the metal surface with a scum. With 0.01 per cent Al the metal surface was nearly entirely covered. Additions of 0.03 per cent Al and 0.055 per cent Al caused a scum to form over the entire surface of the metal, the scum being much thicker with the 0.055 per cent Al addition.

2) Addition of tellurium to the metal is normally followed by the evolution of fumes from the metal. These fumes are quite dense soon after the addition is made, and gradually fade away until the fuming is almost stopped when the heat is ready to pour. An addition of 0.005 per cent aluminum with the tellurium did not appreciably change this observation, but with the addition of 0.01 per cent aluminum plus 0.01 per cent tellurium the fuming was less dense at the start and seemed to be prolonged. This was more evident when 0.03 per cent and 0.055 per cent aluminum were added. In these instances fumes were evolved at a more even rate, and persisted even while the metal was being poured.

It therefore appears that the aluminum scum was important to the retention of tellurium in the melt. Table 14 gives the comparison between the amount of aluminum added and the amount recovered. The aluminum analysis was made by spectroscopic methods in a commercial laboratory.

Heats N8 and N9 are similar to N7, except for an increase in the silicon content of 1.55 per cent. Although the fracture results of the 4 x 4 x 8 in. casting are listed in Table 13 as mottled, they were unusual in that they were almost gray except for a lightly mottled rim about ¾ to 1 in. thick around the outside. Increasing the addition of tellurium to 0.02 per cent in heat N10 did not change the fracture results.

The addition of 0.005 per cent Al plus 0.01 per cent Te plus 0.003 per cent B in heat N13 gave similar fracture results in the 4 x 4 x 8 in. casting as were obtained from heats N8, N9 and N10. The boron did not appear to increase mottling.

Combining 0.01 per cent Zn as $ZnCl_2$ with an addition of 0.02 per cent Al (heat N11, Table 13) was not helpful in obtaining fracture results different from that expected from an addition of 0.01 per cent Zn as $ZnCl_2$ alone (heats A38, A48, A55 and A56, Table 10).

SUMMARY

Base lines representing the maximum carbon and silicon contents which will permit a 100 per cent white fracture in the 4 x 4 x 8 in. casting under the specified procedure have been presented in Fig. 1, for heats made with no additions; in Fig. 4, for heats with 0.01 per cent bismuth added; in Fig. 8, for heats with 12 or 25 grains water vapor added/cu ft of gas in the atmosphere over the melt and in Fig. 10, for heats with 0.01 per cent tellurium added.

Similar base lines for the 1⅞-in. diameter bar have been presented in Fig. 2, no additions; Fig. 5, 0.01 per cent bismuth added; Fig. 9, 12 or 25 grains water vapor added/cu ft of gas in the atmosphere over the melt and Fig. 11, 0.01 per cent tellurium added. Figure 3 presented the white base line for the 1⅜-in. diameter bar made with no additions.

An addition of 0.005 per cent bismuth has been shown to be equivalent to a 0.01 per cent bismuth addition insofar as obtaining a white fracture is concerned. Similarly, a 0.004 per cent tellurium addition has been shown to produce the same fracture result as obtained with an addition of 0.01 per cent tellurium. The addition of amounts of tellurium or bismuth greater than 0.01 per cent were not found to shift the base lines established with a 0.01 per cent addition. However, the larger bismuth additions resulted in the formation of gas holes in a white fracture which at first glance could be mistaken for

mottle. Two min elapsed between the time the additions were made and the castings poured.

DISCUSSION

In order to increase the effectiveness of bismuth and tellurium additions in so far as obtaining a fully white fracture was concerned, the effect of the addition of two or three agents at the same time was investigated. Combinations were selected that might 1) increase the base lines through additive effects, 2) increase the solubility of bismuth or tellurium in the metal or 3) increase the amount of bismuth or tellurium retained in the melt by retarding its evolution as a vapor.

Combinations of bismuth and water vapor, and bismuth and tellurium were made to note any additive effects tending to move the base line to higher carbon and silicon contents. However, the fracture results obtained were similar to that expected from the addition of bismuth or tellurium alone.

Attempts to increase the solubility of bismuth in the iron were made with the following combinations: bismuth-lead, bismuth-indium, bismuth-copper and bismuth-titanium. Except for the bismuth-titanium addition, the effect on mottling was the same as that expected from the addition of bismuth alone. The bismuth-titanium combination was highly graphitizing causing a gray fracture.

The addition of a sufficient amount of aluminum in combination with tellurium was found to aid in the retention of tellurium in the melt by means of the aluminum scum which formed over the melt. Sufficient tellurium was retained so that the fracture of the 4 x 4 x 8 in. casting became white when it would normally have been lightly mottled. Increasing the aluminum addition beyond the optimum amount (0.03 per cent Al, 0.01 per cent Te) caused mottling to reappear.

The effect of temperature of addition was found to be of great inportance. In the case of bismuth, addition at a temperature above its boiling point resulted in a shift of the base line curves to higher carbon and silicon contents than could be obtained with no additions. However, the addition of bismuth at a temperature below its boiling point produced the same fracture as that obtained when no additions were made. Tellurium and water vapor were also in the vapor state when found to be effective in shifting the base line curves.

Addition agents were therefore selected which would be in the vapor state when at the temperature of the molten metal. Unless these materials were involved in chemical reactions or not retained in the metal due to excessive volability, they should be effective in shifting the no addition base line curves to higher carbon and silicon contents.

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APPENDIX

VARIATIONS IN TYPE OF MOTTLING FRACTURES

A large variation was found in the type of mottle obtained in fractures of castings poured as a part of this project. Figure 16 shows an example of the extremely fine mottle specks obtained in one of the 4 x 4 x 8 in. castings. Fine mottle spots were found in those heats which were slightly above the base lines in carbon and silicon content. A slight decrease in either carbon or silicon would cause this fracture to become fully white. On increasing the carbon and/or silicon contents the mottling spots would become more frequent and larger, or the fracture would be gray.

Fine mottle spots were also found in those heats to which additions were made which were slightly above the base line in carbon and silicon content. The fractures obtained from heats to which additions were made were visually the same as those to which no additions were made, when compared at the same position with respect to their appropriate base lines.

Large mottle spots, as shown in Fig. 17, were obtained from heats in which the amount of addition agent was too low. A still smaller addition would result in larger over lapping mottle specks, thus producing a heavily mottled or fully gray fracture. Increasing the amount of the material added would cause this fracture to be 100 per cent white.

CORRELATION OF GRAPHITE SHAPE WITH CARBON AND SILICON CONTENT

Metallographic analysis of microstructures of the 4 x 4 x 8 in. castings made with no additions revealed three types of graphite in the composition range investigated. Figure 18 shows the correlation of those graphite types with carbon and silicon content and with the base lines established for the 4 x 4 x 8 in.

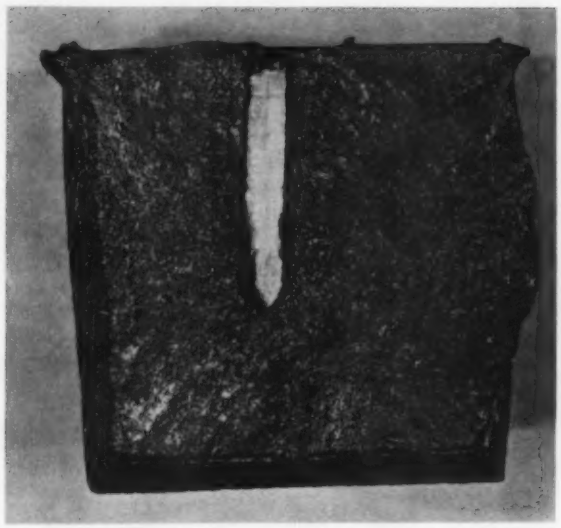

Fig. 16 — Fracture of a 4 x 4 x 8 in. casting showing an example of extremely fine mottle spots obtained from a heat which was too high in carbon and/or silicon content.

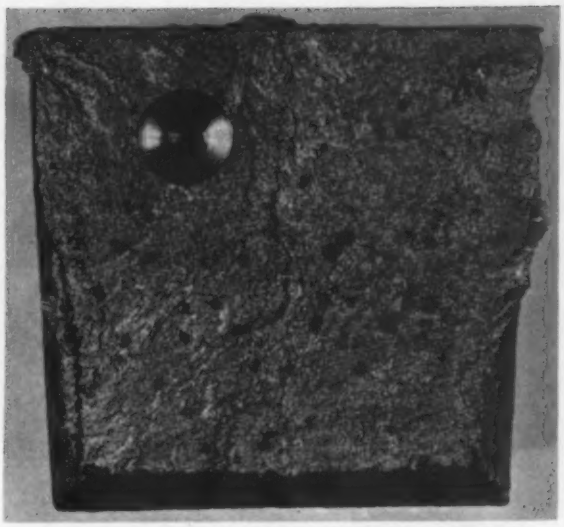

Fig. 17 — Fracture of a 4 x 4 x 8 in. casting showing an example of large mottle spots obtained from a heat in which the amount of addition was too low.

casting with no additions made. Examples of these graphite types are presented in Figs. 19 to 22.

Figure 19 is an example of graphite present in the area marked, "euthectic type," in Fig. 18. This graphite is typical of type D graphite having interdendritic segregation and random orientation.

At lower carbon contents there is less eutectic in the structure. An example of the graphite formed in this region is shown in Fig. 20. The decreased amount of eutectic has resulted in a semi-alignment of the graphite. Evidence of eutectic type graphite is also found in this transition structure.

Film type graphite is found in the area noted in Fig. 18. Figure 21 shows an example of the graphite in this composition range. Long films of graphite, some spreading two or three field diameters of the microscope at 100× before a break occurs, are evident. Eutectic type graphite is no longer present except at the juncture of films.

Figure 22 shows an example of graphite found in the area of compact graphite on Fig. 18. As the carbon content is lowered, the film type of graphite breaks down into short, fat clumps and then into the compact type of graphite. This compact graphite, as seen in Fig. 22, exists for the most part in the region where a visually, fully white fracture was obtained in the 4 x 4 x 8 in. casting. Little or no eutectic is present in this region.

Further work on the correlation of chemical analysis with graphite type from the 4 x 4 x 8 in. casting is underway. The effect of addition agents in the composition ranges studied on the graphite shape will also be investigated.

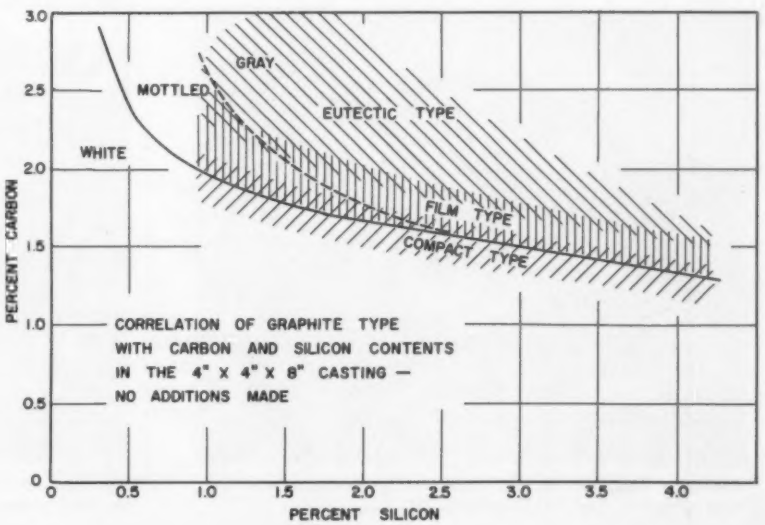

Fig. 18 — Correlation of graphite type in the microstructure with carbon and silicon content and mottling tendency for no additions in the 4 x 4 x 8 in. casting.

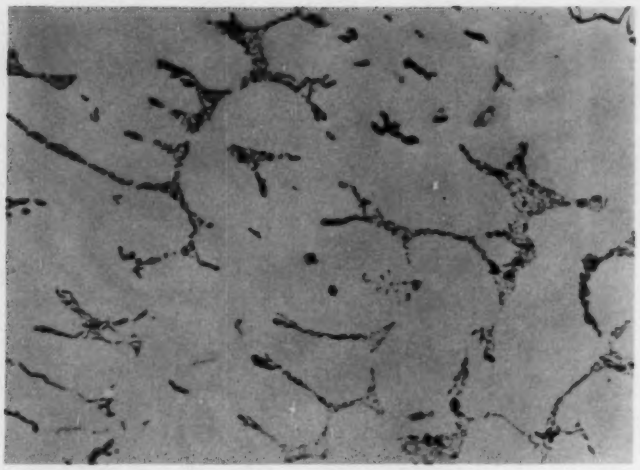

Fig. 19 — Example of eutectic type graphite found in the area noted in Fig. 18. Unetched. 100 ×.

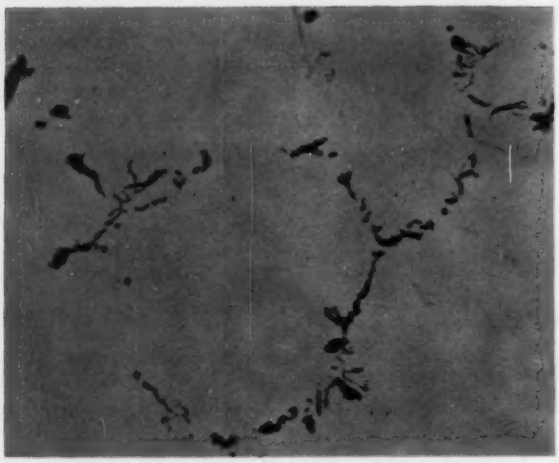

Fig. 20 — Example of transition type graphite between eutectic and film type areas noted in Fig. 18. Unetched. 100 ×.

COMPARISON OF ESTABLISHED BASE LINES WITH COMMERCIAL WHITE IRON ANALYSES

The chemical analysis specifications of white iron produced by ten malleable foundries, presented in Table 15, are reproduced from references.[3,4] The carbon and silicon specification ranges for these irons are plotted with the various base line curves for the 4 x 4 x 8 in. casting in Fig. 23, and for the 1⅞-in. diameter bar in Fig. 24. Foundries A, B, C, D and J have duplexing melting processes while foundries E, F, H, I and K melt by the cold-melt air furnace process.

Figure 23 shows a comparison of carbon and silicon ranges for irons from these malleable foundries with the effect of various additions on the mottling tendency of the 4 x 4 x 8 in. casting. If no additions are made to the melt, and if the metal is melted according to the procedure standardized for this project, the 4 x 4 x 8 in. casting would show mottle in all of the commercial composition ranges. Water vapor in the melting furnace atmosphere moves the base line so that some cold-melt shops can, if the base analysis is right, produce this section fully white.

The addition of 0.01 per cent bismuth allows all of

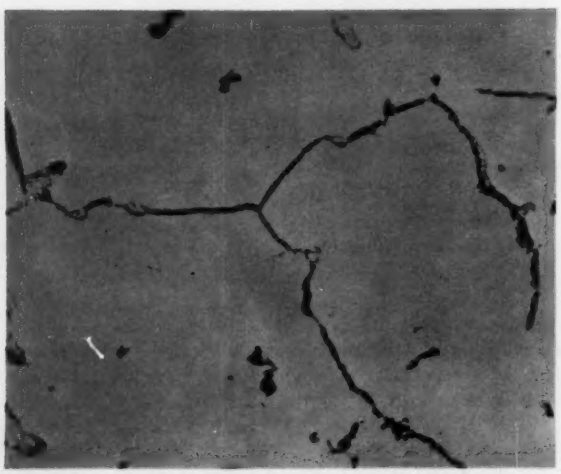

Fig. 21 — Example of film type graphite found in the area noted in Fig. 18. Unetched. 100 ×.

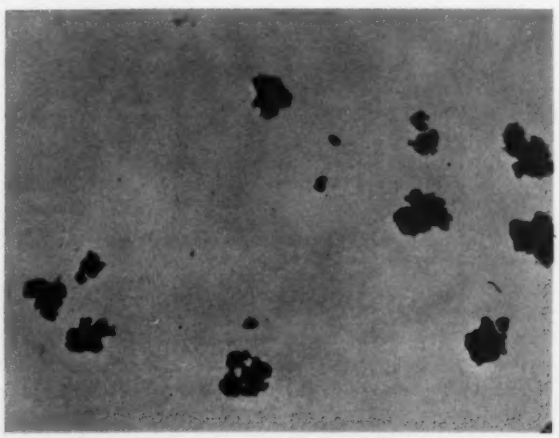

Fig. 22 — Example of compact type graphite found in the area noted in Fig. 18. Unetched. 100 ×.

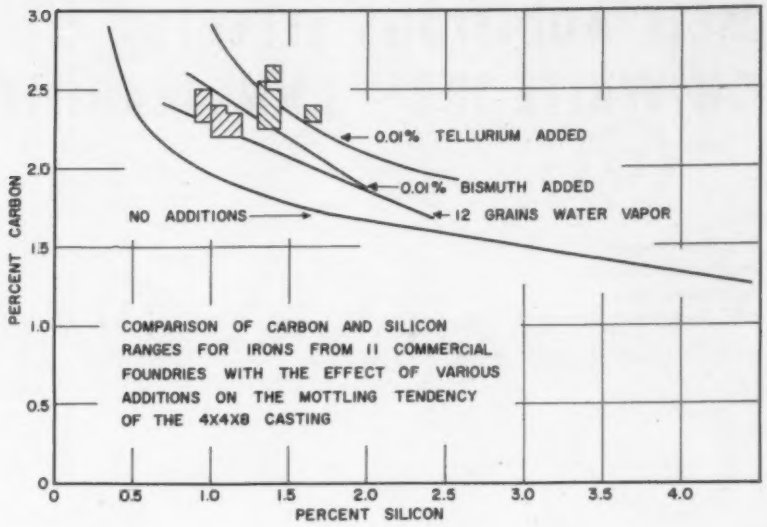

Fig. 23 — Effect of 0.01 per cent tellurium added, 0.01 per cent bismuth added, 12 grains of water vapor/cu ft of gas in the atmosphere over the melt, and no additions on the mottling tendency of the 4 x 4 x 8 in. casting compared with the carbon and silicon ranges for irons from 11 commercial foundries.

the cold melt shops to produce the 4 x 4 x 8 in. casting free from mottle. Mottle will still be obtained in most of the duplex shop analyses. 0.01 per cent tellurium added to the metal moves the base line to higher carbon and silicon contents, and makes it possible to produce a 100 per cent white, 4 x 4 x 8 in. casting in about half of the duplex shop composition ranges.

This same comparison is shown in Fig. 24 for the 1⅞-in. diameter bar. Even when no additions are made, and the metal melted according to the standard procedure, it is possible to produce the 1⅞-in. bar free from mottle in some of the composition ranges reported for cold melt shops. Water vapor in the melt does not appreciably affect the no addition base line in the range of the cold-melt shop analyses. The addition of 0.01 per cent bismuth to the melt allows the production of a fully white fracture in the 1⅞-in. diameter bar for all cold melt compositions and most of the duplex shops. A 1⅞-in. diameter bar free from mottle may be obtained in all duplex melting operations with the addition of 0.01 per cent tellurium.

These curves present a means whereby the effectiveness of certain additions to the melt on the mottling tendency of the 1⅞-in. diameter bar and the 4 x 4 x 8 in. casting may be evaluated.

TABLE 15 — CHEMICAL ANALYSIS OF TYPICAL MALLEABLE FOUNDRY WHITE IRONS[1]

Plant[2]	Chemical Analysis, % C	Si	Mn	S	P	Cr	B
A	2.30-2.40	1.58-1.68	0.44	0.14	0.040	0.030	—
B	2.50	1.25	0.50	0.17	0.08	—	0.0015
C	2.55-2.65	1.35-1.45	0.40-0.46	0.11-0.12	0.05-0.06	0.030	0.0015
D	2.25-2.50	1.30-1.45	0.45-0.50	0.12-0.14	0.06 Max	0.040	0.0020
E	2.20-2.35	1.05-1.20	0.33-0.38	0.07-0.10	0.10-0.14	0.01-0.04	—
F[3]	2.30-2.50	0.90-1.00	0.75-0.85	0.07-0.10	0.10-0.14	0.01-0.03	0.50% Cu optional
H	2.30-2.40	1.00-1.10	0.30-0.35	0.08-0.10	0.13-0.16	—	—
I	2.25-2.35	1.15-1.20	0.33-0.38	0.06-0.08	0.10-0.15	0.036	—
J	2.45-2.55	1.30-1.35	0.36-0.38	0.13-0.14	0.05-0.06	0.044	0.0015
K	2.20-2.40	1.00-1.10	—	—	—	—	—

1. Obtained from reports of AFS Malleable Div. Pearlitic Malleable Committee (6-E).[3,4]
2. Plants A, B, C, D and J are duplex shops. Plants E, F, H, I and K are cold melt shops.
3. Manganese alloyed pearlitic malleable irons.

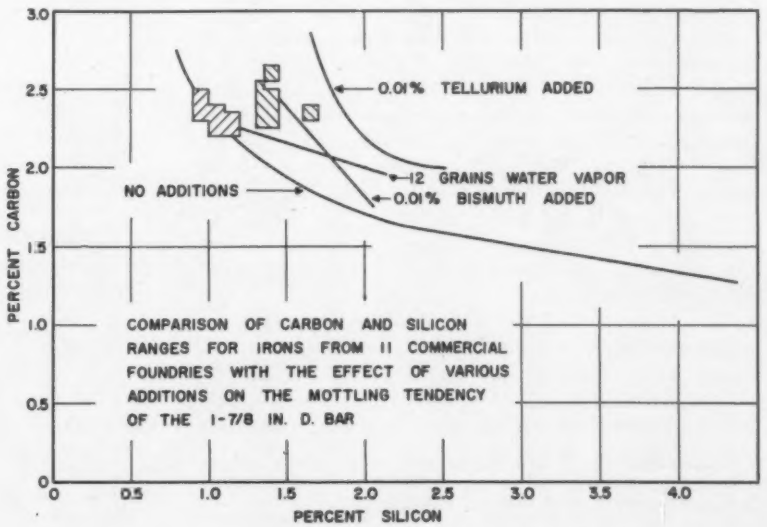

Fig. 24 — Effect of 0.01 per cent tellurium added, 0.01 per cent bismuth added, 12 grains of water vapor/cu ft of gas in the atmosphere over the melt, and no additions on the mottling tendency of the 1⅞-in. diameter bar compared with the carbon and silicon ranges for irons from 11 commercial foundries.

MELT ADDITIONS EFFECTS ON WHITE IRON ANNEALABILITY

Progress Report
Malleable Division
Sponsored by
AFS Training & Research Institute

by C. R. Loper, Jr., R. W. Heine and J. Waring

Part II

ABSTRACT

This report is concerned with the effect of additions to the melt on the annealability of white iron, using the 4 x 4 x 8 in. casting, the 1⅞-in. diameter bar, the 1⅜-in. bar and an annealability test slug which was poured from nearly every heat. First and second stage graphitization, and the effect of additions relative to each, are considered. All work presented here is based on the 1.5 x 0.75 x 0.625 in. annealability slug.

INTRODUCTION

This is the second part of the second progress report on the investigation of casting heavy section malleable iron sponsored by the AFS Training & Research Institute under the direction of the AFS Malleable Division. Part I of this report was concerned with the effect of additions to the melt on the mottling tendency of white iron in various section sizes. This part of the report will be concerned with the effect of additions to the melt on the annealability of white iron.

PROCEDURE

In addition to the 4 x 4 x 8 in. casting, the 1⅞-in. diameter bar and the 1⅜-in. diameter bar used in Part I of this report, an annealability test slug casting was poured from nearly every heat. This casting consisted of 12 annealability test slugs each 1.5 in. long x 0.75 in. high x 0.625 in. wide, and were notched at mid-length for easy fracture. These slugs were adequately fed and attached six per side to a horizontal 1.0 in. square runner, and each gated through a 0.5 in. square gate. The test slugs were all cast in green sand.

The melting procedure and the method of addition to the melt of the additives investigated have been discussed in a reference[1] and Part I of this report.

The furnace installation used for all heat treatments consisted of an electrically heated resistance muffle furnace fitted with an interior separate muffle of 1 in. thick fire clay. Temperature control was of such accuracy that temperatures quoted were ±5 F in all parts of the furnace.

In order to standardize annealing atmospheres, all samples for heat treatment were shot blasted and packed in 2.0 in. diameter x 8 in. long black iron pipes fitted with malleable iron caps. The threads were sealed with a thick graphite paste. The rate of heating in the furnace was controlled so that the FSG temperature was always reached in 3.5 to 7.5 hr. FSG temperatures were more generally reached in 5.5 hr, however. The charge was always placed in a cold furnace, i.e., below 400 F.

In order to compare the results of this work with previous investigations, first stage graphitization temperatures employed were 1700 F. Time at temperatures varied from 0 to 200 hr as required. At the completion of all thermal heat treatments, the containers were quenched in water and allowed to cool in still air.

Examination of FSG structures was carried out at 100×. The completion of FSG was the presence of less than one per cent by area of the carbide phase. Nodule counts on completion of FSG were made by the method of a reference[2] and converted to nodules/mm³ by the method of another reference.[3]

Second stage graphitization was controlled through the range from 1475 to 1300 F in all cases, and cooling rates between 5 and 70 F/hr were employed. The completion of SSG was the appearance of less than one per cent by area at 100× of pearlite or spherodized carbides.

FIRST STAGE GRAPHITIZATION

The results of the investigation of the effect of additions to the melt are presented in Tables 1 through 10. The heats are grouped according to the addition made to the melt, and only the times bracketing the completion of FSG are noted.

Figure 1 presents a summary of the data of first

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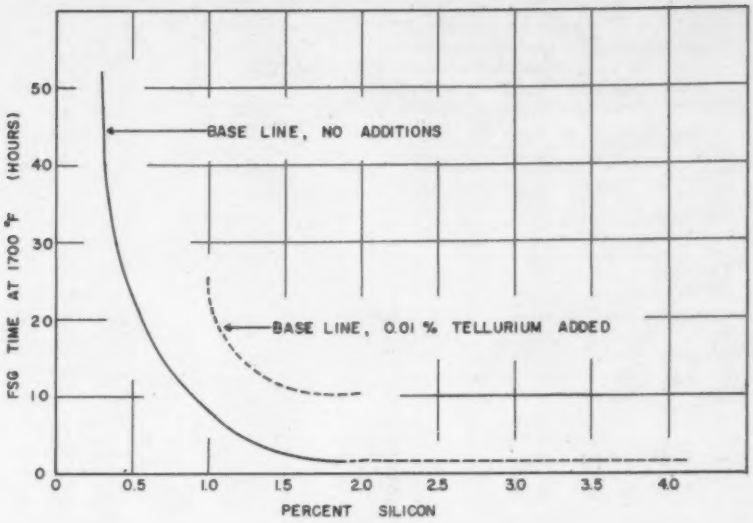

Fig. 1 — Silicon content effect on time required for first stage graphitization at 1700 F for heats with no additions and for heats with 0.01 per cent tellurium added.

stage graphitization time at 1700 F as a function of the silicon content of the heat. Two base lines are drawn, one for 0.01 per cent tellurium added to the melt, and one for heats with no additions made to the melt. These base lines represent the maximum time required for FSG at 1700 F for white irons of various silicon content.

Melt Additions Effect

Additions to the melt of bismuth, thallium, indium and the miscellaneous additions listed in Tables 8 and 9 did not shift the base line (solid curve of Fig. 1) for FSG time at 1700 F. A few exceptions to this base line were found among this group. One of these was heat A 28 (Table 8) to which 0.151 per cent aluminum was added causing the time required for completion of FSG to be greatly increased.

Other heats which did not adhere to the established base line were: heat 38, Table 2 (0.01 per cent Bi added); heat 52, Table 3 (0.05 per cent Bi added; heat 99, Table 6 (0.009 per cent Tl added); heat A 10, Table 7 (0.01 per cent In added); and heat 70, Table 3 (0.05 per cent Bi added). The foregoing exceptions to the base line required FSG times between the solid curve and the dashed curve for 0.01 per cent Te on Fig. 1. These exceptions are readily explained by low nodule numbers of the alloying effect of aluminum in the case of heat A 28. The effect of low nodule numbers will be discussed later.

Tellurium Effect

Figure 1 also presents a base line for heats with 0.01 per cent tellurium added. Additions of tellurium

TABLE 1 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH NO ADDITIONS

Heat No.	Chemical Analyses[1] C, %	Si, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
8	2.39*	1.40*	1	2	5,000+	35
11	2.44*	1.07*	5	7	some flakes	<10
12	2.34*	1.05*	5	7	1,200	< 5
13	2.20*	1.41*	3	4	2,400	5
14	2.12*	1.21*	5	7	2,100	< 5
15	1.85	0.86	10	12	1,200	
16	2.34*	0.95*	7	10	2,100	
17	2.05*	0.82*	10	12	800	
18	2.10	0.86	10	12	3,000	
19	1.90*	1.12*	6	7	700	<10
20	2.00	1.15	5	7	1,800	< 5
21	1.85*	1.40*	4	6	2,600	< 5
22	2.94*	0.30*	200	—	—	
23	2.60*	0.30*	45	50	1,800	
24	1.66*	3.85*	1	3	flakes	>70
25	3.03*	0.25*	135	200	—	
26	1.26*	3.86*	0	2	5,000+	>70
27	1.32*	3.55*	0	1	5,000+	>70
28	1.63	2.00	0	1	5,000+	45-70
29	1.45*	3.96*	0	1	5,000+	>70
30	2.60*	0.26*	135	200	—	
31	2.92*	0.27*	200	—	—	
54	2.11	1.65	1	2	5,000+	45-70
55	2.20*	1.70*	0	1	2,700	20-45
81	1.87*	1.28*	0	2	2,000	5
82	1.76*	2.14*	0	1	5,000+	55-70
83	1.72*	2.20*	0	1	5,000+	55-70
A5	2.60	0.99	7	8	800	<20

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

TABLE 2 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH 0.01 PER CENT BISMUTH ADDED

Heat No.	Chemical Analyses[1] C, %	Si, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
3	2.50*	1.33*	2	3	4,900	10-20
6	2.42*	1.39*	1	2	5,000+	10-20
33	1.88*	2.00*	0	1	5,000+	55-70
34	2.18*	1.41*	0	3	4,200	<10
35	2.59*	1.03*	7	8	1,000	<20
36	1.94*	1.82*	1	2	3,200	10-20
37	2.11	1.30	3	5	4,500	<10
38	2.50	0.70	40	45	100	
39	1.83*	1.89*	0	1	5,000+	55-70
40	2.18*	1.57*	1	2	3,200	10-15
41	2.55*	0.82*	10	12	3,700	
66	2.24*	1.66*	1	2	5,000+	45-70
84	2.30	1.65	2	3	5,000+	20-35

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses have been obtained.

TABLE 3 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH MISCELLANEOUS BISMUTH ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Bi Added, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
4	2.40*	1.30*	0.02	2	3	5,000+	10-20
5	2.36*	1.28*	0.05	3	5	2,700	<10
7	2.40*	1.49*	0.10	2	3	3,200	10-20
9	2.34*	1.42*	0.01[2]	0	1	5,000+	20-45
10	2.41*	1.41*	0.10[2]	1	2	5,000+	20-45
42	2.11	1.65	0.05	1	2	4,800	40-45
52	2.34*	1.68*	0.05	5	6	2,200	10-20
67	2.30	1.65	0.01[3]	0	1	5,000+	35-45
70	2.58	1.65	0.05	10	11	800	10-20
85	2.30*	1.67*	0.01[4]	2	3	4,800	20-35
A13	2.10	1.40	0.05	3	5	5,000+	10-20
A14	2.10	1.40	0.005	5	6	4,200	10-20
A16	2.12*	1.52*	0.0025	3	4	3,200	<10
A18	2.10*	1.43*	0.10	3	4	3,200	5-15
A88	2.51	0.89	0.004	11	—	100	
A89	2.17	1.42	0.004	3	—	1,500	
A92	1.92	1.80	0.004	3	—	1,500	

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses have been obtained.
2. Bismuth added at 2700 F, poured at 2680 F.
3. Bismuth added at 2600 F, poured at 2600 F.
4. Bismuth added at 2700 F, poured at 2600 F.

to the melt as low as 0.002 per cent (heat A 97, Table 5) and as high as 0.10 per cent (heat A 93, Table 5) do not change the base line established for an addition of 0.01 per cent tellurium. This base line for tellurium additions represents the maximum FSG time required at 1700 F, as related to per cent silicon. Many heats containing tellurium additions, however, were completely first stage graphitized at times below that expected from the tellurium base line.

In fact only 13 heats out of 26 required the shift from the silicon base line curve (solid line) to the tellurium addition base line curve (dashed curve, Fig. 1). These 13 heats all were low in nodule number after FSG. Where the nodule number is raised, then the FSG time at 1700 F for heats with 0.01 per cent tellurium added becomes the same as the FSG time when no tellurium is added. The nodule number can be readily increased by methods to be presented later.

An important question concerns the effect of additions on FSG time. Is the effect one of retarding FSG by alloying or by reducing graphite nucleation during annealing? Since the FSG time, at a specified silicon content, is the same for heats of the same nodule number, with or without addition of tellurium or bismuth, it appears as if the effect of these additions is entirely one of changing the nodule number. This is in complete agreement with their effect on mottling tendency. Large additions of these elements do not have any greater effect than the minimum addition on either mottling or annealing, at least in the range of 0 to 0.05 per cent addition.

The reduction in graphite nucleation which minimizes mottling may or may not retard FSG depending on the recovery of the element. Recovery is not known

TABLE 4 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH 0.01 PER CENT TELLURIUM ADDED

Heat No.	Chemical Analyses[1] C, %	Si, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
65	2.19*	1.61*	0	3	4,000	10-20
86	2.82*	1.75*	7	10	3,200	10-20
87	2.25	2.25	0	1	5,000+	>70
88	1.75	2.50	0	1	5,000+	>70
89	2.02*	2.61*	0	1	5,000+	>70
90	2.25	2.00	0	1	5,000+	55-70
91	2.85*	1.56*	7	10	1,000	<10
93	2.89*	0.98*	17	19	700	
94	1.94*	2.53*	0	1	5,000+	>70
95	2.68	1.30	7	10	400	<10
96	2.46*	1.75*	0	1	5,000+	45-55
97	2.73*	1.17*	12	15	200	<20
98	2.36*	1.85*	0	1	5,000+	55-70
A6	2.77	0.99	22	24	150	
A7	2.57	1.40	5	7	3,700	15-20
A8	2.60	0.99	20	23	100	
A9	1.68*	3.38*	7	10	1,200	>70

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

TABLE 5 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH MISCELLANEOUS TELLURIUM ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Te Added, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
51	2.11	1.65	0.05	0	3	4,800	10-20
A15	2.08*	1.62*	0.0027	2	3	5,000+	10-20
A17	2.10	1.50	0.0014	2	3	5,000+	50-55
A19	2.10	1.50	0.137	2	3	2,000	15-35
A85	2.86	0.99	0.004	20	—	100	
A86	2.18	1.59	0.004	6	9	2,500	
A87	1.98	2.52	0.004	6	9	2,400	<25
A93	2.68	1.62	0.10	9	10	1,900	
A97	2.78	0.96	0.002	25	—	100	

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

TABLE 6 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNT AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH THALLIUM ADDITIONS

Heat No.	Chemical Analysis[1] C, %	Si, %	Tl Added, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
78	2.11	1.65	0.009	1	2	5,000+	>70
99	2.77	1.01	0.009	15	20	1,000	<20
A	1.98	2.03	0.01	2	3	5,000+	>70
A1	2.10	1.50	0.009	2	3	2,700	<20
A2	2.50	1.01	0.01	7	10	300	<20
A3	1.93*	1.55*	0.009	0	1	5,000+	<10
A4	2.12*	1.01*	0.009	7	10	1,200	<10
A20	2.10	1.40	0.0025	2	3	5,000+	5-15 (?)
A21	2.10	1.40	0.005	5	7	3,200	(?)
A22	2.10	1.40	0.01	2	3	5,000+	>55 (?)
A23	2.10	1.40	0.05	5	7	3,100	15-35

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

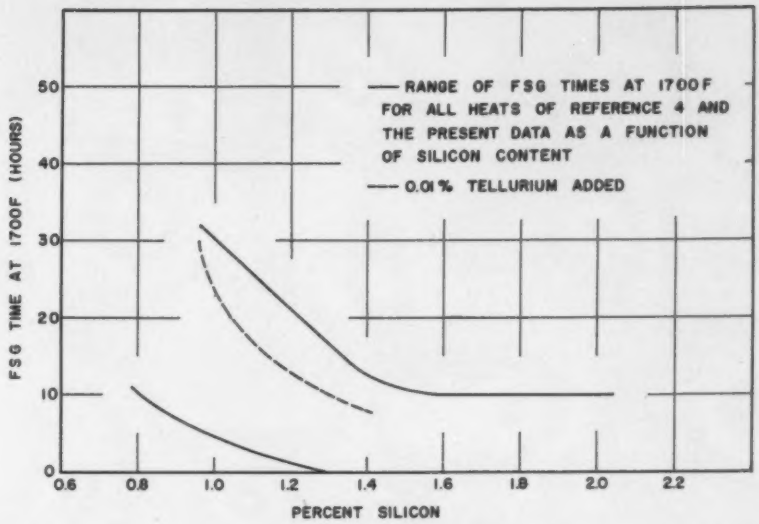

Fig. 2 — Range of first stage graphitization times at 1700 F for all heats, from a reference[4] and the present data, as a function of silicon content shown between the solid lines. The base line for 0.01 per cent tellurium added is shown as a dashed line.

for lack of adequate chemical analysis. Nucleation, however, can be observed after FSG and altered by treatments described later. Obviously, the statements just made do not apply to alloying element additions such as chromium, aluminum, etc.

Additions and Melting Variables Relationship on FSG

The effect of melting variables on first stage graphitization was reported.[4] A summary of the data from this reference[4] and this project is presented in Fig. 2.

The area between the two curves represents the range of times required for FSG at 1700 F, depending on melting variables and additions to the melt. The reference[4] states that minimum FSG times at 1700 F are promoted by reducing melting furnace atmospheres and charge mixtures containing pig iron. On the other hand, factors which raise FSG time at 1700 F toward the maximum include the use of 100 per cent sprue charges, oxidizing melting conditions, high nitrogen content and increase in melt-down time. These melting variables can cause a shift in the relationship between FSG time at 1700 F and per cent silicon from the minimum to maximum curves shown in Fig. 2.

The effect of additions to the melt exhibited a lesser effect on FSG time at 1700 F than melting variables. For example, the base line curve for tellurium additions resulting in a low nodule number, presented in Fig. 1, is also shown in Fig. 2. It is seen to fall between the extremes obtained by the melting variables cited.

Figure 2 also reveals that the time for complete FSG at 1700 F for irons of over 1.50 per cent silicon is always less than ten hours.

SECOND STAGE GRAPHITIZATION

The effect of additions to the melt on the cooling rate necessary for complete second stage graphitization is also presented in Tables 1 through 8, depending on the additions made. Figure 3 presents a compilation of the effects of melting variables and the effects of additions to the melt on second stage graphitization cooling rate between 1475 and 1300 F as a function of silicon content.

The upper curve in Fig. 3 represents the highest cooling rates which produced a fully ferritic structure, while the lower curve represents the slowest cooling rate required to produce a fully ferritic structure. The data on which these curves are based are compiled from this project and from the reference data.[4] Dashed lines are from the reference.[4] According to this reference, factors which promote rapid SSG cooling rates include:

1) Pig iron in the charge.
2) Reducing melting conditions.
3) Low nitrogen contents in the iron.
4) Low moisture content in the melting furnace gases.
5) Proper Mn-S ratio.
6) Low silicon oxidation losses.

Retardation of SSG was reported to be caused by the converse of these factors.

TABLE 7 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH INDIUM ADDITIONS

	Chemical Analysis[1]			FSG Time, Hr			
Heat No.	C, %	Si, %	In Added, %	Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
72	2.11	1.65	0.007[2]	0	3	3,700	15-20
A10	2.50	1.22	0.01	15	20	200	<5
A11	2.10	1.75	0.01	2	3	4,800	15-20
A12	1.78	2.30	0.01	0	2	5,000+	>70
A24	2.10	1.40	0.0025	5	6	2,000	5-15 (?)
A25	2.10	1.40	0.005	5	6	3,700	5-15
A26	2.10	1.40	0.0075	5	6	3,200	<5
A27	2.10	1.40	0.01	0	5	3,200	<5

1. Estimated chemical analysis.

2. Indium added to this heat was produced in the 1940's, whereas all other indium additions were of high purity indium.

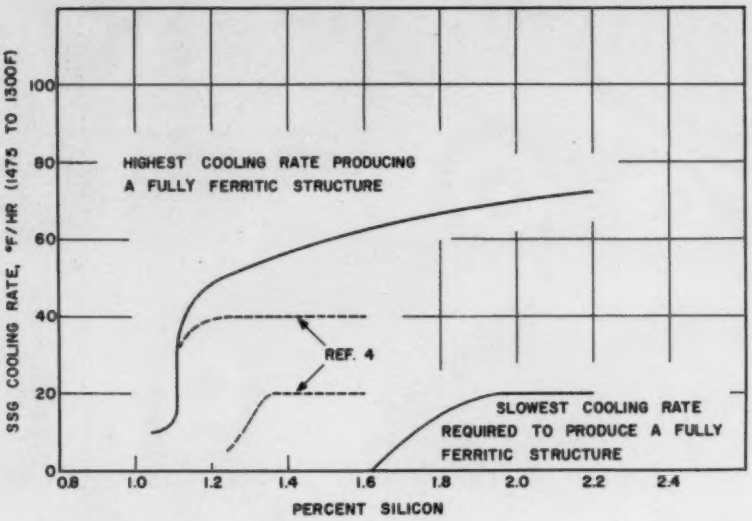

Fig. 3 — Range of second stage graphitization cooling rates (1475 F to 1300 F) as a function of silicon content for the data of the present project (solid curves) and from a reference[4] (dashed curves). The upper curves represent the highest cooling rates encountered which produced a fully ferritic structure while the lower curves represent the slowest cooling rates required which produced a fully ferritic structure.

Nodule Number Effect on SSG

Nodule number has an even greater effect on SSG than it has on FSG. The heats with addition resulting in low nodule numbers cause a slow SSG cooling rate to be required. Analysis of all the data of this project indicated that the principal variable influencing SSG rate was the nodule number rather than the kind or magnitude of the addition at a given per cent silicon.

Figure 4 graphically presents an analysis of the data of this project and one reference.[4] The solid curve, shown in Fig. 4, represents the minimum cooling rate required for SSG (1475 to 1300 F) as a function of the number of nodules present at completion of FSG. For example, if the number of nodules after FSG is 3000, the cooling rate for complete SSG must be 30 F/hr or less. The actual cooling rate required in this case could be lower than 30 F/hr by an amount depending upon silicon content, alloying effects and melting variables. The dotted line, shown in Fig. 4, represents the minimum cooling rate for SSG (1475 to 1300 F) for 95 per cent of all the samples from both projects and has the same implication.

High nodule numbers have been reported to be promoted by reducing conditions and, in general, those conditions which promote mottling. A somewhat similar relationship exists with regard to melt additions in that additions which had little effect on moving the base line for mottling (Part I of this report) to higher carbon and silicon contents also had high nodule counts on completion of FSG.

Additions which reduced mottling sometimes produced high counts and sometimes low nodule counts. This may be a recovery problem. When nodule count was low, the SSG cooling rate required was low and vice versa. In cases where the nodule count was low after normal FSG, but was raised by special treat-

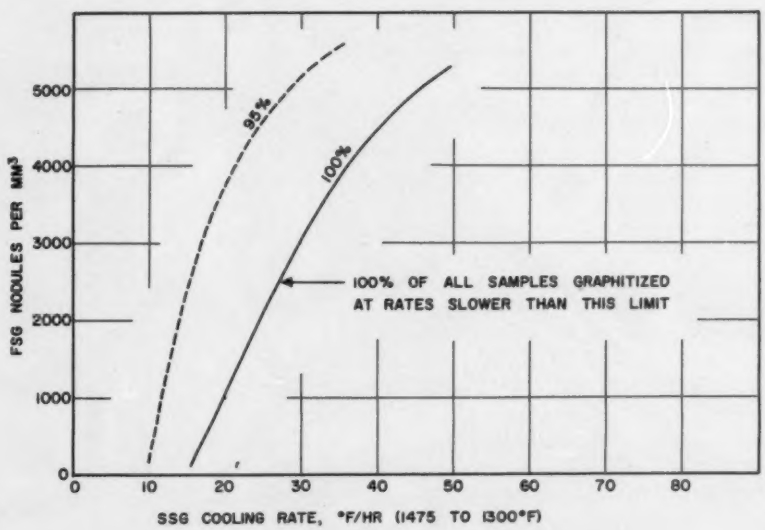

Fig. 4 — Effect of number of nodules at completion of first stage graphitization on second stage graphitization cooling rate (1475 F to 1300 F) necessary for complete second stage graphitization for all heats in a reference[4] and this report.

ment, then the SSG cooling rate was raised to the expected higher cooling rate.

COMBINED ADDITIONS EFFECT ON ANNEALABILITY OF WHITE IRON

The combined addition of bismuth plus water vapor (heat 46, Table 8) and bismuth plus tellurium (heats A 67, A 68, A 71, A 90 and A 91, Table 8) were not investigated because they did not influence mottling behavior differently than the single additions.

The combined addition of aluminum plus tellurium was also studied. The data for these heats are presented in Table 8. Heats N 4, N 5, N 6 and N 7 of about 2.62 per cent C and 1.20 per cent Si, and having from 0.005 to 0.055 per cent aluminum plus 0.01 per cent tellurium added, were first stage graphitized in about 10 hr and contained fewer than 100 nodules/cu mm. Heats N 8, N 9 and N 10 of about 2.62 per cent C and 1.55 per cent Si, and having 0.03 per cent aluminum plus 0.01 or 0.02 per cent tellurium added, were first stage graphitized in 6 to 10 hr and contained 150 to 800 nodules/cu mm as noted in Table 8.

SPECIAL HEAT TREATMENT EFFECT

With the use of a special heat treatment, it was possible to correct for the low nodule count at the completion of FSG obtained in those heats, which did not agree with the no additions base line presented in Fig. 1 and in those heats to which aluminum plus tellurium was added. This cycle consisted of heating to 600 F and holding for 2 hr, heating to 1200 F and holding for 4 hr and finally continuing up to 1700 F for first stage graphitization. The usual procedure was used for second stage graphitization.

Table 9 presents the FSG times, nodule count at completion of FSG and SSG cooling rates for those heats which were given this special heat treatment. A comparison of FSG times and nodule counts for heats given this special heat treatment with FSG times and nodule counts for heats given the regular heat treatment is presented in Table 10.

Table 10 shows that a considerable increase in the nodule count at completion of FSG was obtained in all samples to which the special heat treatment was given. The first stage graphitization times obtained were correspondingly less than those obtained with the regular heat treatment and, as was expected, all of these heats had FSG times equal to or near that predicted by the no additions curve presented in Fig. 1.

The maximum SSG cooling rate obtained from samples given the special heat treatment are presented in Table 9, and compared with samples given the regular heat treatment in Table 10. These SSG cooling rates are, with only one exception, all higher than those obtained using the regular heat treating cycle for FSG. This increase in SSG rate may be directly attributed to the increase in the number of nodules present at the completion of FSG.

TABLE 8 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR HEATS POURED WITH MISCELLANEOUS ADDITIONS

Heat No	Chemical Analysis[1] C, %	Si, %	Addition Made, %	FSG, Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG cooling Rate, F/hr
43	2.10*	1.63*	12 gr H_2O	0	3	5,000+	20-35
44	2.11	1.65	0.01 As	0	3	5,000+	10-20
45	2.11	1.65	0.01 Sb	5	6	3,700	5-10
46	2.12*	1.36*	0.01 Bi + 12 gr H_2O	0	1	5,000+	10-20
47	2.14*	1.40*	12 gr H_2O	5	6	5,000+	15-20
48	2.11	1.65	0.05 Sn	0	3	5,000+	10-15
49	2.11	1.65	0.05 Zn	0	3	5,000+	10-20
50	2.11	1.65	0.05 PB	5	6	5,000+	20
53	2.11	1.65	0.01 Zn	3	5	5,000+	10-20
56	2.11	1.65	0.01 Zn	3	5	5,000+	10-20
57	2.11	1.65	0.01 Zn	0	3	4,200	10-20
58	2.11	1.65	0.01 Ca	0	3	5,000+	10-20
59	2.11	1.65	0.0085 Sr as SrO	3	5	5,000+	10-20
61	2.11	1.65	0.05 Se	0	3	3,200	20
62	2.11	1.65	0.01 Mg	5	6	4,800	20-35
63	2.11	1.65	0.043 Sr as SrO	0	3	5,000+	15-20
64	2.11	1.65	0.01 Se	0	3	3,700	20
71	2.11	1.65	0.02 Ba as $BaCl_2$	0	3	4,000+	10-15
74	2.11	1.65	0.01 Na as NaCl	0	3	5,000+	20-45
75	2.11	1.65	0.005 Li as LiCl	0	3	5,000+	10-20
76	2.11	1.65	0.01 K as Kl	0	3	5,000+	20-35
77	2.11	1.65	0.024 Ce	0	3	5,000+	40-45
79	2.11	1.65	0.01 K as Kl	0	3	5,000+	10-20
80	2.11	1.65	0.02 Bi as Bi_2O_3	1	2	5,000+	20-45
92	2.11	1.65	0.061 Ce	0	3	flake	20-35
A28	1.83	1.20	0.151 Al	20	45	1,200	5-15
A67	2.56*	1.62*	0.01 Bi + 0.01 Te	0	9	2,400	20-25
A68	2.40	1.19	0.01 Bi + 0.01 Te	0	11	1,700	
A71	2.64	1.40	0.01 Bi + 0.01 Te		9	1,300	20-25
A90	2.82	1.00	0.002 Bi + 0.002 Te	25	—	<100	
A91	2.22	1.60	0.002 Bi + 0.002 Te	6	9	2,150	
N4	2.66*	1.18*	0.01 Al + 0.01 Te	10	15	<100	
N5	2.61*	1.20*	0.005 Al + 0.01 Te	6	10	<100	
N6	2.65*	1.20*	0.055 Al + 0.01 Te	6	10	<100	
N7	2.67*	1.22*	0.03 Al + 0.01 Te	10	15	<100	
N8	2.62*	1.56*	0.03 Al + 0.01 Te	6	10	800	
N9	2.59*	1.54*	0.03 Al + 0.01 Te	6	10	200	
N10	2.66*	1.55*	0.03 Al + 0.02 Te	6	10	150	

1. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

TABLE 9 — FIRST STAGE GRAPHITIZATION TIMES, NODULE COUNTS AT COMPLETION OF FSG AND SECOND STAGE GRAPHITIZATION COOLING RATES FOR MISCELLANEOUS HEATS FIRST STAGE GRAPHITIZED ACCORDING TO A SPECIAL HEAT TREATMENT[1]

Heat No.	Chemical Analysis[2] C, %	Si, %	Addition, %	FSG Time, Hr Greater than	Less than	Nodules/ mm³	Max. Complete SSG Cooling Rate, F/hr
38	2.50	0.70	0.01 Bi	12	15	3,700	<25
52	2.34*	1.68*	0.05 Bi	0	3	5,000+	25-32
86	2.82*	1.75*	0.01 Te	0	3	3,500	32-40
91	2.25	2.00	0.01 Te	0	3	5,000	25-32
93	2.89*	0.98*	0.01 Te	6	9	2,900	<25
95	2.68	1.30	0.01 Te	0	3	4,000	<25
97	2.73*	1.17*	0.01 Te	4	6	1,700	<25
A7	2.57	1.40	0.01 Te	0	3	5,000+	32-40
A8	2.60	0.99	0.01 Te	6	9	4,500	<25
A9	1.68*	3.38*	0.01 Te	3	4	4,400	<25
A14	2.10	1.40	0.005 Bi	0	3	5,000	<25
A28	1.83	1.20	0.151 Al	0	4	5,000+	<25
A69	2.56*	1.69*	0.01 Te	0	3	5,000+	32-40
A85	2.86	0.99	0.004 Te	6	9	4,200	<25
A86	2.18	1.59	0.004 Te	0	3	5,000+	<25
A87	1.98	2.52	0.004 Te	0	3	5,000+	>40
A93	2.68	1.62	0.10 Te	3	4	5,000+	25-32
A97	2.78	0.96	0.002 Te	6	9	5,000	<25
N4	2.66*	1.18*	0.01 Al + 0.01 Te	0	4	3,900	<25
N5	2.61*	1.20*	0.005 Al + 0.01 Te	0	4	3,900	25-32
N6	2.65*	1.20*	0.055 Al + 0.01 Te	0	4	5,000+	>40
N7	2.67*	1.22*	0.03 Al + 0.01 Te	0	4	5,000+	25-32
N8	2.62*	1.56*	0.03 Al + 0.01 Te	0	3	3,000	>40
N9	2.59*	1.54*	0.03 Al + 0.01 Te	0	3	4,900	25-32
N10	2.66*	1.55*	0.03 Al + 0.02 Te	0	3	3,300	25-32
N13	2.55	1.55	0.005 Al + 0.01 Te + 0.003 B	0	3	5,000+	>40
N16	2.02	1.50	0.02 Al + 0.004 Te	0	3	5,000+	32-40

1. Heated to 600 F, held 2 hours; heated to 1200 F, held 4 hours; heated to 1700 F, held 15 hours.

2. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

ALUMINUM EFFECT ON STRUCTURE OBTAINED AFTER ANNEALING

Metallographic examination of the fully malleablized samples to which aluminum was added revealed the presence of an additional phase when the amount of residual aluminum was about 0.02 per cent. This phase was present whether the aluminum was added in combination with another element, such as tellurium, or whether it was added alone. The amount of this additional phase increased as the amount of residual aluminum increased. Table 11 presents the results of spectrographic analyses of some of the heats to which aluminum was added and the presence of the residual phase.

The presence of this residual phase has been discussed in a reference.[8] It was found in that work that small percentages of aluminum and titanium added to white cast irons function initially as deoxidizers, while amounts sufficient to leave a residual alloying percentage form complex carbides in the malleablized iron. The former behavior promotes graphitization and ultimately mottling.

A rather complete description of this phase is presented in another reference.[9] These authors name it the K-phase, and on the basis of x-ray data, chemical data and metallographic and equilibrium diagram studies, describe it as a double carbide of aluminum and iron.

According to one reference,[8] the presence of the K-phase does not impair mechanical properties until the residual aluminum content is greater than 0.02 to 0.04 per cent.

SUMMARY

The effect of silicon content on the minimum time required to accomplish complete FSG at 1700 F has been established, Fig. 1. Carbon content does not appear to alter the relationship between minimum time for FSG and per cent silicon.

The effect of Bi and Te on the per cent Si-FSG time relationship depends on whether these additions change the number of nodules formed during annealing. If the number of nodules is decreased then a longer time is required, as indicated by the upper dashed curve in Fig. 1. If the number of nodules is not decreased, or if the number is increased by pretreatment, then Bi and Te have no effect on the relationship of FSG time and per cent silicon. Thus, Bi and Te have no direct effect of retarding FSG by alloying in the range of additions studied, 0 to 0.10 per cent.

The maximum time, which might be required for FSG, is related to per cent Si, as shown in the upper curve Fig. 2. Melting variables and ladle additions of Bi and Te may require an actual FSG time between the minimum and maximum curves in Fig. 2, depending on the extent to which nodule number is decreased. With pretreatment to obtain a full nodule count, the minimum time requirement accomplishes FSG. The data show that nodule counts over 2500 nodules/cu mm permit FSG to occur in the minimum time for a given per cent silicon.

The maximum cooling rate permissible to accomplish complete SSG is related to per cent Si in the iron, as shown in Fig. 3. The minimum cooling rate which may be required for complete SSG is related to silicon content, as shown by the lower curve in Fig. 3. The actual cooling rate required for SSG will fall between these two cooling rates, depending on the number of nodule developed during FSG as related to melting variables, ladle additions and any potential alloying elements.

Ladle additions of Bi and Te have no effect of retarding SSG if a sufficient number of nodules are present after SSG (This is the same principle stated previously).

A high nodule number, over 2500 nodules/cu mm,

may still require a minimum SSG cooling rate, if some other effect such as nitrogen in the iron, alloying with excess chromium, manganese or aluminum or melting variables, etc., is a controlling factor.

All of the work presented in this paper has been based on the 1.5 x 0.75 x 0.625 in. annealability slug described in the procedure. The effect of section size on the above mentioned conclusions is presently being studied.

In addition to the references listed at the end of this paper, there appears an extensive bibliography on the effect of addition elements on the graphitization of white cast iron.

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TABLE 11 — ALUMINUM RECOVERY DETERMINATION[1] AND PRESENCE OF RESIDUAL PHASE AFTER COMPLETE MALLEABLIZING

Heat No.	Al added, %	Al found, %	Residual phase present
A 28	0.151	not determined	Yes
N 4	0.01	0.005	No
N 5	0.005	0.004	No
N 6	0.055	0.025	Yes
N 7	0.03	0.017	slight
N 8	0.03	0.020	slight
N 9	0.03	0.024	Yes
N 10	0.03	0.022	Yes

1. Analyses made by spectrographic methods.

TABLE 10 — COMPARISON OF FSG TIMES FOR HEATS GIVEN A SPECIAL HEAT TREATMENT[1] WITH FSG TIMES FOR HEATS GIVEN THE REGULAR HEAT TREATMENT[2]

Heat	Chemical Analyses[3]			Regular Heat Treatment[1] FSG Time, Hrs			Max. Complete SSG Cooling	Special Heat Treatment[1] FSG Time, Hr			Max. Complete SSG Cooling
No.	C, %	Si, %	Addition, %	Greater than	Less than	Nodules /mm³	Rate, F/hr	Greater than	Less than	Nodules /mm¹	Rate, F/hr
38	2.50	0.70	0.01 Bi	40	45	100	10-20	12	15	3700	<25
52	2.34*	1.68*	0.05 Bi	5	6	2200	10-20	0	3	5000+	25-32
86	2.82*	1.75*	0.01 Te	7	10	3200	<10	0	3	3500	32-40
91	2.25	2.00	0.01 Te	7	10	1000		0	3	5000	25-32
93	2.89*	0.98*	0.01 Te	17	19	700	<10	6	9	2900	<25
95	2.68	1.30	0.01 Te	7	10	400	<20	0	3	4000	<25
97	2.73*	1.17*	0.01 Te	12	15	200	15-20	4	6	1700	<25
A7	2.57	1.40	0.01 Te	5	7	3700		0	3	5000+	32-40
A8	2.60	0.99	0.01 Te	20	23	100	>70	6	9	4500	<25
A9	1.68*	3.38*	0.01 Te	7	10	1200	10-20	3	4	4400	<25
A14	2.10	1.40	0.005 Bi	5	6	4200	5-15	0	3	5000	<25
A28	1.83	1.20	0.151 Al	20	45	1200		0	4	5000+	32-40
A85	2.86	0.99	0.004 Te	20	—	100		6	9	4200	<25
A86	2.18	1.59	0.004 Te	6	9	2500	<25	0	3	5000+	<25
A87	1.98	2.52	0.004 Te	6	9	2400		0	3	5000+	>40
A93	2.68	1.62	0.10 Te	9	10	1900		3	4	5000+	25-32
A97	2.78	0.96	0.002 Te	25	—	100		6	9	5000	<25
N4	2.66*	1.18*	0.01 Al + 0.01 Te	10	15	<100		0	4	3900	<25
N5	2.61*	1.20*	0.005 Al + 0.01 Te	6	10	<100		0	4	3900	25-32
N6	2.65*	1.20*	0.055 Al + 0.01 Te	6	10	<100		0	4	5000+	>40
N7	2.67*	1.22*	0.03 Al + 0.01 Te	10	15	<100		0	4	5000+	25-32
N8	2.62*	1.56*	0.03 Al + 0.01 Te	6	10	800		0	3	5000	>40
N9	2.59*	1.54*	0.03 Al + 0.01 Te	6	10	200		0	3	4900	25-32
N10	2.66*	1.55*	0.03 Al + 0.02 Te	6	10	150		0	3	3300	25-32

1. Heated to 600 F, held for 2 hr; heated to 1200 F, held 4 hr; heated to 1700 F, held 15 hr.

2. Heated to 1700 F, held 10 to 15 hr.

3. Estimated chemical analyses unless marked with an asterisk (*) for which actual chemical analyses were obtained.

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Circle No. 173, Page 165

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NEWS and VIEWS

Highlights of 64th AFS Castings Congress
Picture Tour of Exhibits and Meetings
Spotlight on New Foundry Equipment

Nelson Stresses Research In Foundry Future

AFS President C. E. Nelson, left, congratulates N. J. Dunbeck on his election as the 1960-61 Society President.

Elect Dunbeck As President

Norman J. Dunbeck, elected AFS President 1960-61 at the AFS Annual Business meeting on May 11, has been active in the foundry business since 1924. He served as an AFS National Director 1948-1951, as AFS Vice-President 1959-60.

In addition, he was a founding member and past chairman of the AFS Central Ohio Chapter and has worked on several of the AFS technical committees.

In 1926 he joined Eastern Clay Products, Inc., to establish a control laboratory on synthetic sand binders and in 1928 became assistant to the president. He became vice-president and general manager in 1936 and when Eastern Clay Products was acquired by International Minerals & Chemical Corp. in 1958 he was named as vice-president.

He holds several patents on foundry sand binders and treatments and has written many articles for technical journals.

Circle No. 174, Page 165

A promising future, based on a dynamic approach to problems, was outlined to foundrymen at the 64th AFS Castings Congress and Exposition held May 9-13 at Philadelphia. Such a program includes increased research, aggressive merchandising and a realistic evaluation of the industry.

AFS President C. E. Nelson urged development of a more dedicated research program by the industry. He said, "I strongly recommend that we should make it a top priority plan to spend much more on worthwhile projects that will markedly upgrade casting products and processes."

Hoyt Memorial Lecturer William J. Grede, warned that the industry must have the dogged determination never to stop searching for a solution, no matter how many failures may be encountered in the attempt. See page 43 in this issue for highlights of Grede's talk, and page 59 for the complete text.

Throughout the five-day convention, foundrymen were warned that they must take all steps necessary to reverse the downward trend in casting production and regain their share of the fabrication market. They were reminded of the present inadequate merchandising programs and their failure to exploit the advantages of castings—flexibility, quality and economy.

Nelson stressed that the industry must take stock of the trends in the industry, noting that the total casting industry has not grown in tonnage during the past ten years and that the number of foundries has decreased slightly. He pointed out that while conventional sand casting has dropped quite substantially, the more automated processes of permanent mold and die castings have grown rather spectacularly.

In analyzing the current direction of the industry he remarked:

"One only need look at the plans being made by the automotive industry in the areas of die casting and automated permanent mold casting to see that low labor, automatic, efficient, high yield processes are the trend of the day . . . I leave with you the points that our basic foundry industry, its metals, its methods, its markets are on the move and we must be certain that we, as members of the industry and as members and planners of our Society, are alert to adjust to and keep ahead of these changes."

The tone of the convention was optimistic. More than 200 exhibitors occupying 90,000 square feet proved the availability of tools for all phases of the industry and foundries regardless of size. New equipment and techniques were shown capable of meeting the inroads of competition. Numerous working exhibits scattered throughout the three halls drew crowds interested in seeing equipment demonstrations.

Wednesday morning was devoted to AFS activities. Included were President Nelson's address, the Hoyt Memorial Lecture, presentation of 1960 Robert E. Kennedy Memorial Contest Awards, AFS Service Citations and AFS Awards of Scientific Merit. AFS Vice-President N. J. Dunbeck was elected as the new President and Albert L. Hunt was named as Vice-President. Six Directors were also elected at the Annual Business Meeting. Pictures of the newly elected officers and directors will be found on page 126.

Service Citations were awarded to William M. Ball, Jr., R. Lavin &

Sons, Inc., Chicago, and Victor E. Zang, Unitcast Corp., Toledo, Ohio. Awards of Scientific Merit were presented to George P. Halliwell, H. Kramer & Co., Chicago, and George A. Timmons, Climax Molybdenum Co., Detroit.

Winning apprentices and their castings and patterns will be found on page 34.

At the annual banquet, AFS Gold Medals, the highest honor given by the Society, were presented to Samuel F. Carter, Jr., American Cast Iron Pipe Co., Birmingham, Ala., W. W. Levi, consulting metallurgist, Radford, Va., and Theron D Stay, Reynolds Metals Co., Cleveland.

A humorous talk by Dr. Bergen Evans of the English Department, Northwestern University, Evanston, Ill., was given at the banquet.

Research papers presented by the Society's technical divisions and general interest committees emphasized the depth in technical skill and the concentrated efforts of investigators in seeking new technical breakthroughs. Monthly publication of TRANSACTIONS papers in MODERN CASTINGS stimulated discussion periods following the talks.

To ensure a smooth operating technical program, daily breakfasts were attended by authors and session chairmen with AFS Technical Director S. C. Massari.

An expert analysis of the immediate and future importance of the papers will be found in this issue, starting on page 29.

The technical program was supplemented by shop courses, luncheons and dinners sponsored by the divisions. Shop courses were held at night to accommodate foundrymen in the Philadelphia area.

More than 200 speakers and panelists took part in the program. Included were 65 representing foreign and Canadian industry. A capacity crowd at the Sand Division Dinner heard Prof. D. C. Williams present the Russian paper, *Foundry Production in the U.S.S.R.* by Dr. Ylian A. Nekhendzi, who was unable to make his trip to the United States. Important Russian developments in his talk will be found on page 41.

Other foreign speakers came from England, Belgium and Australia. R. R. Woodward and H. J. Proffitt presented a report on British die casting practices in aluminum sponsored by the Institute of British Foundrymen. W. B. Parkes and R. G. Godding of the British Cast Iron Research Association, Birmingham, England, and E. C. Lewis, Alumnasc, Ltd., Northamptonshire, England, were also Congress speakers.

The latest Australian findings on the effects of variation of some physical and chemical conditions on properties of bentonite suspensions were presented by A. J. Anderson and G. J. Sutton of the University of New South Wales.

Prof. A. De Sy, University of Ghent, Belgium, spoke on gray iron impact testing, and K. Schneider, Aluminumwerke, Nurenburg, Germany, talked about aluminum grain refining.

A. E. Murton, Department of Mines and Technical Surveys, Ottawa, Ont., Canada, gave a report on Canadian non-ferrous and iron foundry sand practices. Other Canadian papers were also presented.

Name Hunt As Vice-President

Albert L. Hunt, elected as Vice-President 1960-61 at the AFS Annual Business meeting on May 11, has been in the foundry business most of his career and served as an AFS Director, 1951-1954.

He is a past chairman of the AFS St. Louis Chapter and was chairman of the Foundry Educational Foundation's industrial advisory committee for the University of Missouri School of Mines and Metallurgy, Rolla, Mo. Hunt began his career as a draftsman for the Mississippi Valley Structural Steel Co., St. Louis, in 1928, later working in a similar capacity for St. Louis Frog & Switch Co. and the city of St. Louis. He joined the American Brake Shoe Co. National Bearing Div., St. Louis, in 1936 and was successively machine shop superintendent, sales engineer, plant superintendent, works engineer and vice-president of operations.

A. L. Hunt

After 24 years of service with American Brake Shoe Co., Hunt in 1959 joined Superior Foundry Co., Cleveland, as executive vice-president.

New National Directors

R. R. Ashley

A. E. Falk

W. C. Jeffery

T. T. Lloyd

J. T. Moore

C. E. Nelson

W. E. Sicha

D. E. Webster

Banquet speaker Dr. Bergen Evans, Northwestern University, asks, "Where Do We Go With Brains."

National Director A. J. Moore and wife, Montreal, Quebec, head receiving line at the Canadian Dinner.

Mrs. C. E. Nelson, right, serves cup of tea to Mrs. N. J. Dunbeck, left, while Mrs. E. A. Zeeb, co-chairman of the Philadelphia entertainment committee observes.

Sixty years in the foundry industry have been compiled by C. T. Wilson, foundry superintendent, Oil City Iron Works, Corsicana, Texas. Watching Wilson sign the Old Timer's book are Doris Larson, and National Director D. E. Webster, American Laundry Machine Co., Rochester, N. Y.

GOLD MEDAL AWARDS . . . for outstanding service to the Society and castings industry were presented at the annual banquet. Presentations were made by I. R. Wagner, third from left. Winners are: W. W. Levi, T. D. Stay and S. F. Carter, Jr. (top, below)

CITATIONS AND AWARDS . . . were made at the annual business meeting by I. R. Wagner, third from left. Service Citations were given to W. M. Ball, Jr. and V. E. Zang. Awards of Scientific Merit were won by G. P. Halliwell and G. A. Timmons. (middle, below)

APPRENTICE WINNERS . . . were honored at the annual business meeting. First place winners shown with Education Chairman Jess Toth are: Adam Kravetz, wood patternmaking; James C. Leinss steel molding and Peter E. Durben, non-ferrous molding. Standing: C. D. Lee, metal patternmaking and Arvo Tynilainen, iron molding. (bottom, below)

TOURING THE SHOW

More than 200 exhibitors from the United States, Canada and overseas displayed the latest equipment and techniques to 12,460 visitors in Philadelphia's Convention Hall.

1—Before the Exposition could open it had to pass the AFS President's official inspection. Here we see R. F. Nosek, C. B. Jenni, C. V. Nass, N. J. Dunbeck and C. E. Nelson examining the new Beardsley & Piper automated shell core blowing machines.

2—R. Sweitzer listens to M. Kirsch describe the melting advantages of Carborundum's ferrocarbo briquets.

3—First public showing of an International Minerals and Chemical Corp. new product—the Cupoliner "77"—attracted the attention of this group of foundrymen. It's designed for one man automatic operation!

4—The winner of the National Engineering Company's Handlebar Harry contest is shown on the right after 44 years of service in the foundry of Dominion Coal Co., Ltd., Glace Bay, Nova Scotia. Winning entry was submitted by W. Phillips, company foundry superintendent, shown with his wife, receiving prize of 10 day all expense tour to Hawaii.

5—Archer-Daniels-Midland Co. unveiled their new furan resin binder for cores which harden by chemical reaction rather than baking. Anton Dorfmueller (center) tells two foundrymen how this 800 lb volute core was made using the furfural binder.

6—Pangborn Corp. salesman C. E. Pretzinger completes sale of this rotoblast tableroom to T. Graning of Graning Enameling Co., El Monte, Calif.

7—F. E. North America, Ltd., created the realism of foundry operations with this large installation of equipment for sand handling, continuous mulling, ton-a-minute sand slinging, flaskless molding, and shell core blowing. Like many other of the exhibitors, practically all of this equipment was sold off the floor to foundries intent on modernization.

8—George Pfaff of Wheelabrator Corp. explains some features of their new 22 cubic foot super tumblast designed for automatic operation.

TOURING THE SHOW . . .

Equipment emphasis dealt heavily with automation, mechanization, and over-all speed up of foundry operations.

9—G. E. Smith, Inc. sales engineer A. H. Ciaglia (right) tells foundryman how this 2400-lb core was cured in wood box with their cold cure process.

10—Quiet radiant gas heat furnace made by Lindberg Engineering Co. allows the gas-air mixture to seep through porous bricks and burn on surface.

11—Lester B. Knight (right) points out a feature of materials handling on this scale model of a proposed steel foundry modernization.

12—Foundrymen observe demonstration of this new, fully automatic, one-man operated, mold blowing, CO_2 gassing machine of Carver Foundry Products Co.

13—Crowd gathers at Baroid Chemicals, Inc., exhibit to watch water-less sand molds made and souvenir aluminum castings poured.

14—Big attention-getter at the Harry W. Dietert Co. booth was this antique 1911 Brush runabout restored by H. W. Dietert, shown at the wheel.

15—Co-op exhibit had Frank G. Hough Co. front-end loader dumping sand into Royer Fdry. & Mach. Co. shake-out sand cleaner which discharged into Clearfield Mach. Co. skip-hoist and muller system.

16—J. P. Keating of Neenah Foundry Co. studies operating features of Shalco shell core/mold blower made by National Acme Co. Unit is fully automatic using air for control and operation.

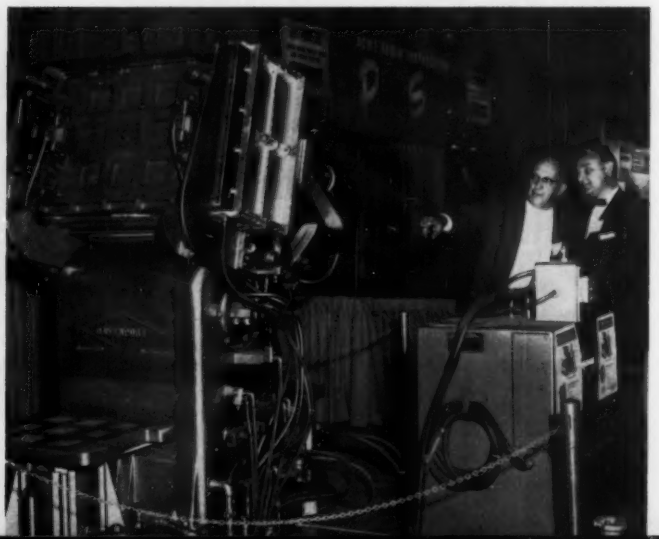
17—European trend toward high speed automated production of CO_2 cores accounts for the design of this Roper automatic core shooting and gassing unit. Three boxes are mounted on rotating turntable. Machine was exhibited by Hansberg Shooters, Inc.

TOURING THE SHOW...

18—Foundryman W. B. Misch listens to explanation of Claude B. Schneible Co. cupola dust collector from Sales Engineer J. Ross.

19—Booth of Corn Products Div., Corn Products Sales Co. is beehive of discussions involving the use of corn-base core binders.

20—Fully pneumatic and automatic is this roll-over machine made by Davenport Machine & Foundry Co.



21—Another breakthrough—nickel carbonyl patterns were displayed for the first time at the AFS Exposition by The Budd Co.

22—Epoxy spray gun attracted attention at the U.S. Gypsum Co. booth as a new technique for saving up to 60 per cent time in making glass cloth laminated patterns.

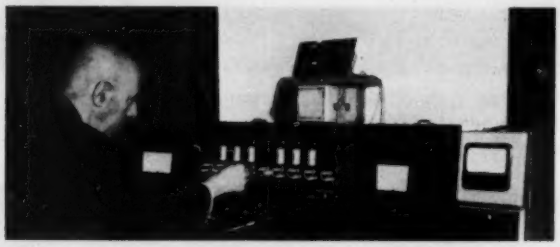
23—This automatic shell sand coating plant dries, heats, and coats 10,000 lb of sand per hour . . . exhibited by C & S Products Co.

24—Freeman Supply Co. salesman W. Dashiell, on left, just sold this Wadkin universal pattern miller to P. M. Bowers, third from left, Bowers Pattern Works, Battle Creek, Mich.

25—This 5000 lb capacity induction furnace can operate off 60 cycle current and save buying expensive motor-generator equipment . . . exhibited by Ajax Magnethermic Corp.

Co-authors of "Ladle Additions to Hypo-Eutectic Gray Cast Iron" receive division's award for best paper from vice-chairman Harvey Henderson, center. Authors are D. J. Harvey, C. L. Langenberg, D. D. McGrady, and H. L. Womochel.

Session vice-chairman R. J. Moser demonstrates a point prior to start of Die Casting & Permanent Mold session. Seated are authors D. N. Williams, E. C. Kron, D. R. Edgerton, and V. D. Sweeney. Standing are G. T. Piper and W. F. Schmidt.



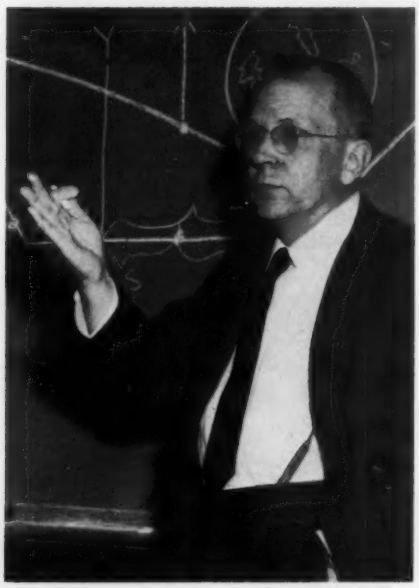
Dr. Victor Paschkis, Columbia University, New York, demonstrates analogue computer used in compiling statistical data in heat transfer research.

Technical Session Highlights

Five days of technical sessions, workshops, and symposiums by the AFS divisions and general interest committees brought the latest research data to an international audience of foundrymen attending the 64th Castings Congress.

AFS Technical Director S. C. Massari, right, spoke on "Marketing Your Product" at pattern luncheon. Others are W. E. Mason, J. M. Kriener, and R. L. Olson.

Sand session chairmen and authors review arrangements. Seated are A. E. Murton, G. J. Vingas, and D. C. Williams. Standing are C. A. Robeck, R. H. Olmsted, and George DiSylvestro.



H. L. Womochel, Michigan State University, uses a phase diagram to illustrate a point in his discussion of fundamental behavior of gray iron.

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Circle No. 147, Page 165

AFS-TRAINING & RESEARCH INSTITUTE

1960 EDUCATIONAL COURSES

JUNE—JULY

Subject and Description	*Dates*	*Course Length (Days)*	*Where Given*	*Course Fee*
Production of Ductile Iron	**June 27-29**	**3**	**Chicago**	**$60**
Melting equipment and melting practices are emphasized for lowering production costs. All phases of production are presented—metallurgy, inoculants, quality control, pouring practices, raw materials and inspection methods. Specialized course for all foundry personnel producing ductile iron or contemplating entering this casting field. **Course No. 7**				
Blue Print Reading, Estimating	**July 11-13**	**3**	**Chicago**	**$60**
Basic fundamentals and principles necessary when considering new jobs. Job analysis techniques are presented in logical step-by-step procedure . . . including the initial reading of blueprints to production planning. Practical methods of estimating new jobs are studied, emphasizing "danger points" which can increase production costs. This course covers information which is vitally important for economically successful foundry operations. Key personnel involved in these responsibilities can learn new techniques. **Course No. 8**				

REGISTRATION: Make reservations for all 1960 AFS-T&RI training courses by course numbers and dates given. Registrations accepted in order as received at AFS Headquarters, Golf & Wolf Roads, Des Plaines, Ill.

AFS-T&RI Course Outlines Shell Molding Principles

An intensive three-day study of shell cores and molds with experts in the field serving as instructors was presented April 11-13 in Chicago by the AFS-Training & Research Institute.

Sand selection, synthetic resins, dry mixtures of sand and resin and coated sands were discussed by O. Jay Myers, Foundry Products Div., Reichhold Chemicals, Inc., White Plains, N. Y.; Robert Klem, Auto Specialties Mfg. Co., Benton Harbor, Mich.; and G. E. Ceebin, National Engineering Co., Chicago.

Pattern and core box equipment and molding and core machines were outlined by Ray Olson, Southern Pattern Works, Birmingham, Ala. Pasting or clamping of cores, pouring, tests and controls required and shell molding and core defects were taught by John Smillie, John Deere & Co., Moline, Ill.

Dimensional tolerances, metals that can be cast in shells, relative cost of the shell process and its economic and other advantages were given by Harold C. Grant, Dearborn Iron Foundry, Ford Motor Co., Dearborn, Mich.

An achievement test and discussion were conducted by T&RI Training Supervisor R. E. Betterley.

Examples of shell cores hold the interest of foundrymen at the Shell Molds and Cores course given by the AFS Training & Research Institute in Chicago.

Left to right are visitor Leo Dennie, Black Products Co., Chicago; G. Adams, Chicago Malleable Castings Co., Chicago; R. Glass and W. Loucks, National U. S. Radiator Corp., Johnstown, Pa., and Raymond A. Kern, Link-Belt Co., Indianapolis.

Examining shell molds at the AFS—T&RI course given April 11-13 in Chicago are L. W. Czarnecki, Bendix Aviation Corp., St. Joseph, Mich.; William Downey, United Shoe Machinery Corp., Beverly, Mass.; S. K. Mukherjee, Shree Baidyanath Iron & Steel Co., India.

Also William M. Carr, Evinrude Motors Div., Outboard Marine & Mfg. Co., Milwaukee; instructor Harold C. Grant, Dearborn Iron Foundry, Ford Motor Co., Dearborn, Mich.

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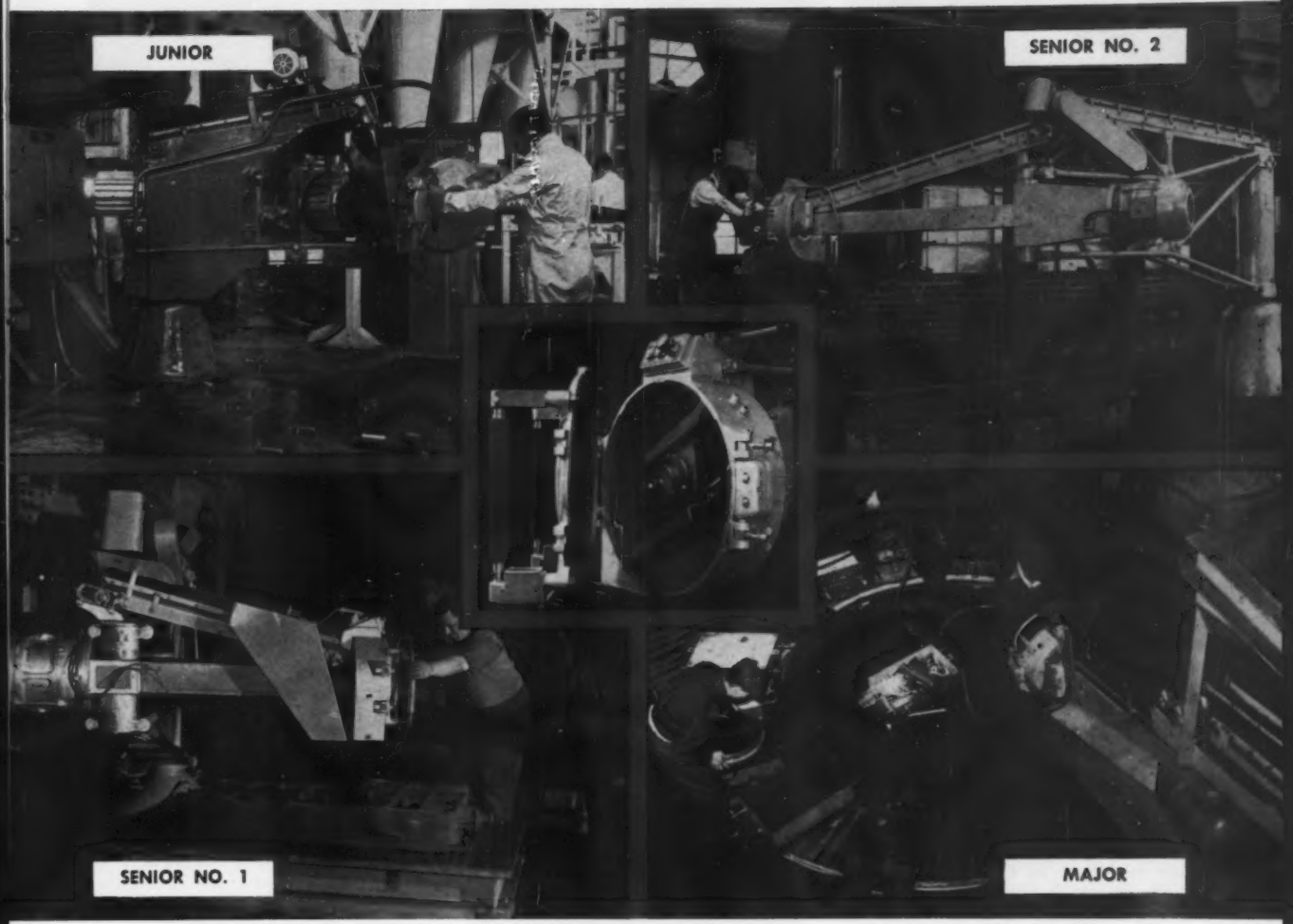

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Circle No. 148, Page 165

Victor Rowell, Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland, puts cores in oven at committee project.

Burdette Jones, John Deere Waterloo Tractor Works, Waterloo, Iowa, and J. C. Dixon, Cities Service Oil Co., East Chicago, Ind., prepare sand mixture.

Blowing of test cores is observed by LeRoy Taylor, far right, Ottawa Silica Co., Ottawa, Ill. at Golden Foundry Co.

Committee 8-J Does Own Work On Veining Investigation

A working committee on the veining cores, with committee members doing the work was held March 28 by Committee 8-J at Golden Foundry Co., Columbus, Ind.

How this group—Physical Properties of Iron Foundry Molding Materials at Elevated Temperatures Committee of the Sand Division—functions was explained to Columbus citizens in the press and on radio. Pictures of the committee were furnished by the Columbus Evening Republic.

Committee operations were explained on radio station WSCI by LeRoy E. Taylor, Ottawa Silica Sand Co., Ottawa, Ill., chairman of the committee. Clarence Bowman, Golden Foundry, committee vice-chairman, also spoke on the veining problem and Joseph Essex, Vice-President, Golden Foundry, explained the importance of the investigation from a production standpoint.

The investigation included a review of literature, gating procedures and mold wall movement; risering practices; calculations of gates and risers for several castings of simple geometric shapes cast in both green and dry molding sands for a high strength and soft gray iron; and several aspects associated with risering such as feeding distance of risers, solidification mechanism of gray iron, inoculation and mass effect.

Charles Jelinek, Ford Motor Co., Cleveland, runs tensile strength test on cores.

Research Project Report Available

Gating and Risering of Gray Iron Castings, a 45-p summary of a research project sponsored by the AFS Training & Research Institute at Case Institute of Technology, Cleveland, under the direction of the Research Committee of the AFS Gray Iron Division, is now available to members for $3.75. The non-member price is $5.

Included in the report is *Gating and Risering Gray Iron Castings*, a summary report on literature surveyed by J. F. Wallace, associate professor, department of metallurgical engineering, Case Institute. A second section is *Gating of Gray Iron Castings* by Wallace and E. B. Evans, research associate, department of metallurgical engineering. Wallace and Evans also authored two other sections, *A Review of Mold Wall Movement* and *Risering of Gray Iron Castings*.

Twelve tables are included in the appendix dealing with recommended gates and risers.

Books may be ordered through the Book Department, American Foundrymen's Society, Golf & Wolf Roads, Des Plaines, Ill.

Name Jeter As New Director

E. Claude Jeter, manufacturing manager of foundries, Engineering & Foundry Div., Ford Motor Co., Dearborn, Mich., has been elected as an AFS Director. He succeeds Louis J. Pedicini, Lester B. Knight & Associates, now located in Zurich, Switzerland, who resigned in March due to his extended European assignment.

Jeter has been associated with Ford Motor Co., since 1928, starting as a chemist, rising to plant manager of the Ford Cleveland foundry in 1950, serving in that capacity for nine years prior to assuming his present position in July, 1959.

E. C. Jeter

Members of the Sand Division Executive Committee meeting in April at Chicago. G. J. Vingas, Magnet Cove Barium Corp., Arlington Heights, Ill.; G. E. Schultz, Reliable Castings Co., Cincinnati; E. C. Zirzow, Werner G. Smith, Inc., Cleveland; AFS Technical Director S. C. Massari.

Also Victor Rowell, Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland; L. E. Taylor, Ottawa Silica Co., Ottawa, Ill.; L. Winnings, Wagner Castings Co., Decatur, Ill.; A. G. Linley, L. F. M. Div., Rockwell Mfg. Co., Atchison, Kans.; J. S. Schumacher, Hill & Griffith Co., Cincinnati.

Malleable Finishing & Inspection Committee meeting in Chicago: Guest E. F. Krieger, R. E. Elsea, L. E. Sutton, A. R. Lindgren, W. L. Olson, Jr., AFS Technical Director S. C. Massari, Chairman Kay Hunsaker.

Wentworth Student Members Participate in Open House

More than 10,000 visitors, including the general public, prospective students, teachers, guidance directors, parents and industry representatives attended an open house, March 30, at Wentworth Institute, Boston.

Students operated equipment in each of the departments with members of the AFS Wentworth Institute Student Chapter giving demonstrations in the casting department.

Recently an integrated overhead sand system and portable sand mixer has been made available to the department by National Engineering Co., Chicago, with the help of the AFS New England Chapter.

The Wentworth Student Chapter was admitted to the Society in 1959. The school offers both day and night courses. Day courses, all of which are two-year, post-secondary school programs, are offered only to high school graduates with adequate secondary school preparation in mathematics and sciences. Students may major in metal processes industries offered in foundry operations, metal fabrication or heat treatment of metals.

Display of castings produced by Wentworth Institute students.

James Lochhead operates equipment for visitors at the Wentworth Institute open house.

Washington Chapter

Discuss Centrifugal Casting

An illustrated talk on the centrifugal casting process was presented at the March meeting by Nathan Janco, Centrifugal Casting Co., Tulsa, Okla.

Various types of equipment were shown for both horizontal casting (where the metal poured is first weighed or measured) and vertical casting where the mold is merely filled. Horizontal casting is used for casting pipe and tubing. Vertical casting is employed for gear blanks, impellers, multiple cavity molds.

The process is used because: it's the only successful way to make stainless steel tubing; of ability to cast thin-walled castings; of an inherent low rejection rate. Also, the process is economical.

At present iron pressure pipe and soil pipe represent the largest production of centrifugal castings. Diameters up to 54 in. and lengths up to 33 ft are produced.

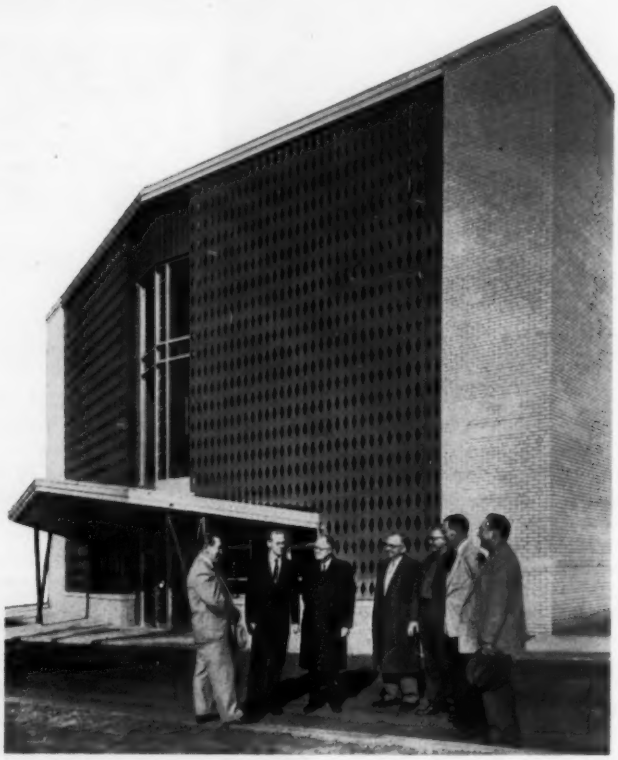
Other observations by Janco: The process lends itself to the jobbing foundry as well as the production foundry . . . various metals can be laminated, the only requirement being that the higher melting point metal be poured first . . . depending upon the number off, as well as other pertinent factors, a centrifugal casting might be produced in a sand, graphite, cast iron, steel or water-cooled steel mold . . . machines built for centrifugal casting are designed to function properly even though the molds may not be in good balance . . . the metal must be poured while the mold is spinning and must continue until it is solidified . . . steel gear blanks may be cast centrifugally with a 70 per cent yield . . . providing a casting is adaptable to the process, a more nearly perfect casting can be made with greater ease than by any other method . . . every castable material yet found, including non-metallic materials, can be cast successfully by the process. —by Hubert L. Rushfeldt

Bibliography on Shell Molding Available

A 26-p bibliography of shell molding, containing important American and foreign references from 1945 to 1960 is now available from the Book Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill. Price to members is $2; the non-member price is $3.

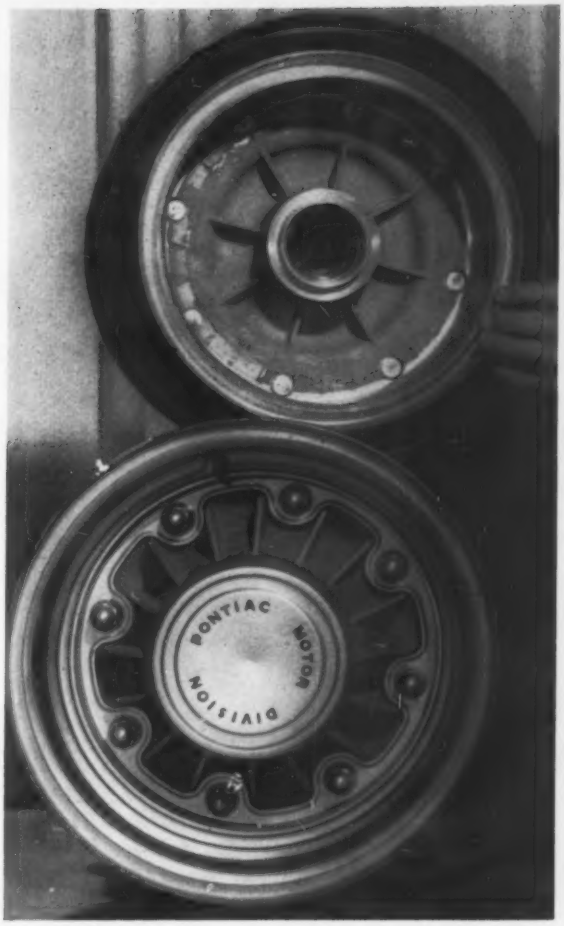
Here's How

. . . metalcastings are doing a better job, foundries are solving production problems, new products are resolving in-plant headaches. If you have an appropriate contribution for this department, send it to the editor of Modern Castings.



. . . 480 cast Tenzaloy aluminum panels create an unusual facade for shielding windows of the Immanuel Baptist Church, Tulsa, Okla., from direct sunlight. Panels were cast by Progressive Brass Mfg. Co. in Tulsa. Each section measures 18 x 24 x ¼ in. and has three diamond-shaped holes. One surface of pattern was covered with rough grain plastic to give a decorative pebble finish.

. . . to keep operator's hands out of trimming or straightening presses in a malleable shop. Lake City Malleable Co., Cleveland, has eliminated worries about hand injuries by handcuffing both wrists to cables. Cables (indicated by arrows) pass behind operator, up through a conduit, back over his head and attach to head of press. Every time press head moves downward it pulls cables and both hands back from in under the closing dies on the press.



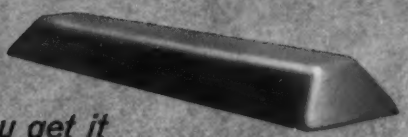
. . . Aluminum and gray iron castings work together in complete compatibility. Pontiac cars now have available bi-metallic integral wheel-drums which virtually eliminate braking "fade-out" and add 50 per cent to brake-lining life. Cast iron friction liner is centrifugally cast and then molecularly bonded into a finned aluminum casting made in permanent molds. Now the brakes run 100 F cooler because of rapid heat transfer and dissipation by the aluminum.

. . . Malleable iron casting saved 38.7 per cent for an agricultural machinery maker. Part was formerly made at cost of 68.5 cents by flattening a length of steel tube and drilling hole (shown at right). Now Lancaster Malleable Castings Co., Lancaster, Pa., cores the hole and casts six links to a mold for only 42 cents apiece. Casting is on left.

. . . Cast aluminum parts provide trouble-free service for automatic washers and dryers made by Maytag Co., Newton, Iowa. Die castings pictured here are 1) wringer washer lid, 2-1/2 lb; 3) damper, 1 lb; 4) pulley, 1-1/3 lb; 5) impeller, 1-1/4 lb; and 6) mounting stem, 2/3 lb. The other two castings shown are made in permanent molds—2) gear housing, 4-3/4 lb, and 7) gear housing cover, 4-1/3 lb.

perfect

CONTROL...



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CHAPTER NEWS

NORTHERN CALIFORNIA—Centrifugal castings were discussed at the March meeting by Nathan Janco, Centrifugal Castings Co., Tulsa, Okla. Shown are Chapter Vice-President Hugh Prior, Superior Electrocast Foundry Co.; Director H. M. Nystrom, H. M. Nystrom Co.; Michael E. Ginty, Vulcan Foundry Co. —by E. J. Ritelli

MICHIANA—An analysis of in-plant communications was given at the March meeting by R. H. Clarke, Dalton Foundries, Inc., Warsaw, Ind., shown on left of Chapter Chairman R. E. Hull, Castings Service, Inc., LaPorte, Ind.

On right is W. H. Voll, Sibley Machine & Foundry Co., South Bend, Ind., who talked on ways the production man in the plant can influence the sales of his company's products. —by A. J. Stanczyk

CENTRAL ILLINOIS—Veining and penetration were described at the March meeting by George DiSylvestro, American Colloid Co., Skokie, Ill.

A vein was defined as the bleeding of metal at a hot spot. Normally a vein creates a porous area. Fire clay is the cheapest and best material for eliminating veins. However, iron oxide is also recommended.

Shown are Technical Chairman Raymond Nash, Caterpillar Tractor Co.; Bert Neilson, S. Obermayer Co.; speaker George DiSylvestro.—by Charles H. Bavis

CANTON—Attending the April meeting were AFS National Director R. E. Mittlestead and Regional Vice-President F. J. Pfarr.

Pfarr retired from the AFS Board of Directors following the 1960 Convention after a three-year term.—by Charles Stroup

NORTHWESTERN PENNSYLVANIA—Chapter Chairman W. E. Eccles, Cooper-Bessemer Corp., chats with visitor W. A. Mehner, Chas. A. Krause Milling Co., Milwaukee.

PITTSBURGH—March speaker F. W. Boulger, Battelle Memorial Institute, Columbus, Ohio, left, poses with Chapter President James D. Wilson, Bronze Die Casting Co., and Chapter Vice-President W. D. Hacker, Mesta Machine Co.—by Walter Napp

PITTSBURGH—Group from Jones & Laughlin Steel Co. attending the March meeting include Stephan Perlaky, Howard Miller, Frank Smak, James Heron and Hans R. Seth. Seth, a native of India, is studying methods and procedures.—by Walter Napp

Utah Chapter

Centrifugal Casting Session

Centrifugal castings were discussed at the March meeting of the Utah Chapter by Nathan Janco, Centrifugal Casting Machine Co., Tulsa, Okla. He stated that virtually all metals lend themselves to centrifugal casting.

If the shape of the casting is such that it can be centrifugally cast, the usual result is higher yield, lower cost and increased speed. Among the subjects discussed were mold thickness, heat inertia and the importance of keeping the peak temperature variation to a minimum for increased mold life.—by J. M. Bushnell

Rochester Chapter

Co_2 in Non-Ferrous Foundries

Speed of hardening, accomplished without application of heat, accounts for much of the popularity of the CO_2 process, W. A. Mader, Oberdorfer Foundries, Inc., Syracuse, N. Y., told Rochester foundrymen at the April meeting.

Mader outlined the results compiled by Oberdorfer which experimented with the process in 1953 and has used the process on a production basis since 1954. Today, approximately 35 per cent of dry sand cores and molds at the Syracuse plant (a sand foundry) and 90 per cent of dry sand cores at the Oswego plant (a permanent mold foundry) are produced by CO_2.

Two sands are used for CO_2 cores and molds. One is a coarse grade, rounded grain, three-screen sand of approximately 60 AFS fineness. The other is a fine grade sub-angular screen sand of approximately 170 AFS grain size number. They are used in varying proportions from 100 per cent of each to give the surface required.

Close tolerances may be held with CO_2 molds and cores because of the hardening method. Castings have been held on a 30-in. diameter within ± 0.030 in.—by Haerle Wesgate

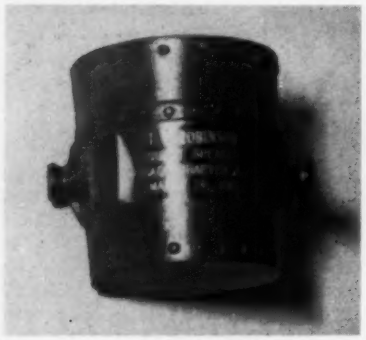
Philadelphia Chapter

New Coreroom Practices

"Most new ideas in the coreroom have come from Europe, but some new startling research ideas have developed in this country," Anton Dorfmueller, Archer-Daniels-Midland Co., Cleveland, told Philadelphia foundrymen at the April meeting. In a demonstration, Dorfmueller mixed lake sand in a small muller added catalysts, then a resin binder. In a short time cores made from mix set without the application of heat.—by E. C. Klank.

NORTHWESTERN PENNSYLVANIA—W. L. Adams, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill., emphasizes point in discussing pressure molding.—by Walter Napp

MO-KAN—Walter Jaeschke, Whiting Corp., Harvey, Ill., on right, discussed new cupola design and operation at the April meeting. On left is Chapter Chairman Charles Ossenfort, Fairbanks, Morse & Co.—by H. L. Mead



CHICAGO—Speakers appearing at the monthly meetings are awarded models of a pouring ladle. The pattern was given to the University of Illinois foundry department with engineering students making the castings.—by George DiSylvestro

PHILADELPHIA—New developments in the coreroom were discussed at the April meeting by Anton Dorfmueller, Jr., Archer-Daniels-Midland Co., Cleveland. Left to right: Chapter Chairman E. A. Zeeb, Dodge Steel Co., speaker Dorfmueller and Technical Chairman Robert F. Schmidt, Ajax Metal Div., H. Kramer & Co.—by Leo Houser, E. C. Klank

CANTON—Sand reclamation was discussed at the April meeting by C. E. Wenninger, Beardsley & Piper Div., Pettibone-Mulliken Corp., Chicago.

Shown are Chapter Chairman R. J. Bossong, American Steel Foundries, Alliance, Ohio; speaker Wenninger and Program Chairman F. A. Dun, Babcock & Wilcox Co.

ST. LOUIS—Edward Walsh, center, secretary, Foundry Educational Foundation, described the needs and contributions of F.E.F. at the April meeting.

Flanking Walsh on the left is AFS Regional Vice-President Webb L. Kammerer and on the right is Chapter Chairman R. E. Hard. —by W. E. Fecht

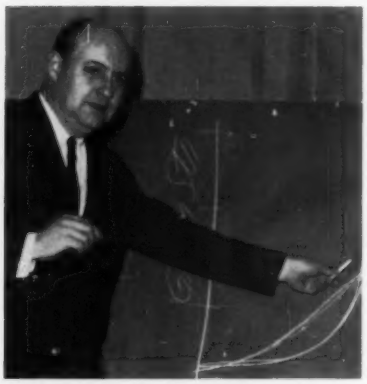
ST. LOUIS—Proper use and care of crucibles were explained at the April meeting by Ralph Ratthyen, Jos. Crucible Corp., Jersey City, N. J.

Ratthyen on the right, is being welcomed by Technical Chairman J. O'Bee, Bronze Alloys Co.—by W. E. Fecht

PHILADELPHIA—New officers and directors include, left to right, directors F. T. Schaefer, Philadelphia Coke Co., Philadelphia, and Maurice Lippincott, Florence Pipe Foundry & Machine Co., Florence, N. J.; Robert C. Stokes, Crown Non-Ferrous Foundry Co., elected as chairman, receives gavel from chairman E. A. Zeeb, Dodge Steel Co., far right.—by Leo Houser, E. C. Klank

NORTHWESTERN PENNSYLVANIA—Seated at the head table during the March meeting are Arthur Osterbard, Diamond Alkali Co., and Harold Buchanan and William Wilmot, Urick Foundry Co.—by Walter Napp

MEXICO—Jose Ramon Albarran y Pliego, Fundidora de Aceros Typeyac, S.A., assumes chairmanship of the Mexico Chapter.—by Ing. Fausto I. Trevino



WISCONSIN—R. J. Mulligan, Archer-Daniels-Midland Co., outlines principles in discussing new techniques in the use of binders for foundry sands at the April meeting in Milwaukee.—by Bob DeBroux

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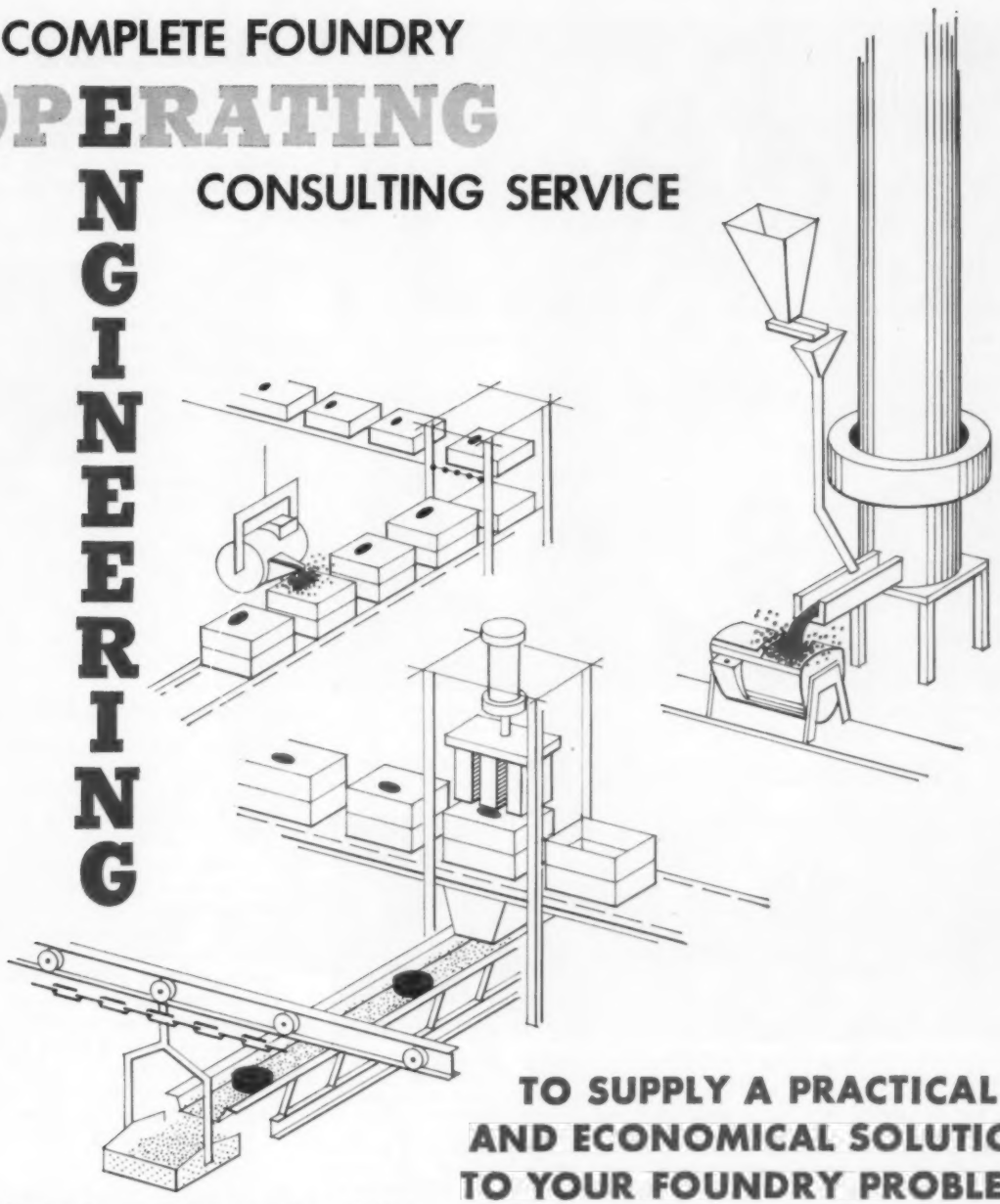

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Circle No. 151, Page 165

NORTHEASTERN OHIO—Shell cores and molds were discussed at the April meeting. Shown are: Allen Hill, Durez Plastics Div., Hooker Chemical Corp.; Lauren Hexamer, SPO, Inc.; moderator Robert Mulligan, Archer-Daniels-Midland Co.

Also: Marvin Wolf, Standard Brass Foundry, Inc.; Charles Jelinek, Ford Motor Co. Cleveland foundry.—by Harold Wheeler

WESTERN NEW YORK—Officer and director nominees are: Dan Pohlman, Pohlman Foundry Co., director; Ron Turner, Queen City Sand & Supply Co., vice-chairman; Bruce Artz, Pangborn Corp., Secretary.

Edward O'Connell, American Standard Radiator, chairman; Leonard Greenfield, Samuel Greenfield Co., treasurer; Jules Hubble, Chevrolet-Tonawanda Div., GMC, Director.—Don Kreuder

PHILADELPHIA—Foundrymen, including Miss H. Toye, Toye Foundry Co., Bridgeton, N.J., visited the Philadelphia Coke Co. plant in the final session of the chapter's educational program. Thirty certificates were awarded by E. X. Enderlein, H. G. Enderlein Co. Plant guides were J. Templin, first row, second from left; H. DeHoll, first row, extreme right; and E. C. Klank, first row, far left. Instructor Ed Saks is in first row, fourth from left.

Each year the Philadelphia chapter sponsors this educational program giving a practical knowledge of how a sand casting is made. Included is green sand molding with various types of patterns both on the bench and floor, coremaking, melting and pouring, and handling of metal.

WISCONSIN—J. R. Vinette, Evinrude Motors Div., outboard Marine & Mfg. Co.; speaker T. Miller, Falk Corp.; and S. Kline, Crucible Steel Castings Corp., talk about cast-weld construction techniques.—by Bob DeBroux

CHICAGO—Al DiGirolamo, Electrocast Steel Co., left, served as moderator at April air-set core session. Dick Szarz, Federal Foundry Supply Co. Div., Archer-Daniels-Midland Co. and Leo Marinelli, Kensington Steel Co. were speakers.—by George DiSylvestro

Detroit Chapter

Shell Molding Process

An illustrated talk on current and possible future applications of the shell molding and core process was given at the April meeting by Raymond Sutter, Sutter Products Co., Holly, Mich.

R. Sutter

Examples of both foreign and domestic uses of the process were covered including the latest phase—the "X" process. Advantages and limitations were also discussed. E. Renshaw, Ford Foundry, England, currently visiting foundries in this country, was a guest.

Six college students from the Detroit area attended the AFS Convention, sponsored by the Detroit Chapter.—by J. R. Young

Eastern Canada

Improving Casting Finish

Trends toward improving casting finish were discussed at the April meeting by Clyde A. Sanders, American Colloid Co., Skokie, Ill. Sanders observed during his trip to Europe that quality and appearance in castings had not been sacrificed for production.

He cautioned foundrymen to watch their molding practices in order to meet competition from other fabrication methods at home as well as from foundries abroad. He stated that green sand molding is one of the most economical methods and that close control of sand properties gives good finish and quality.—by James Cherrett

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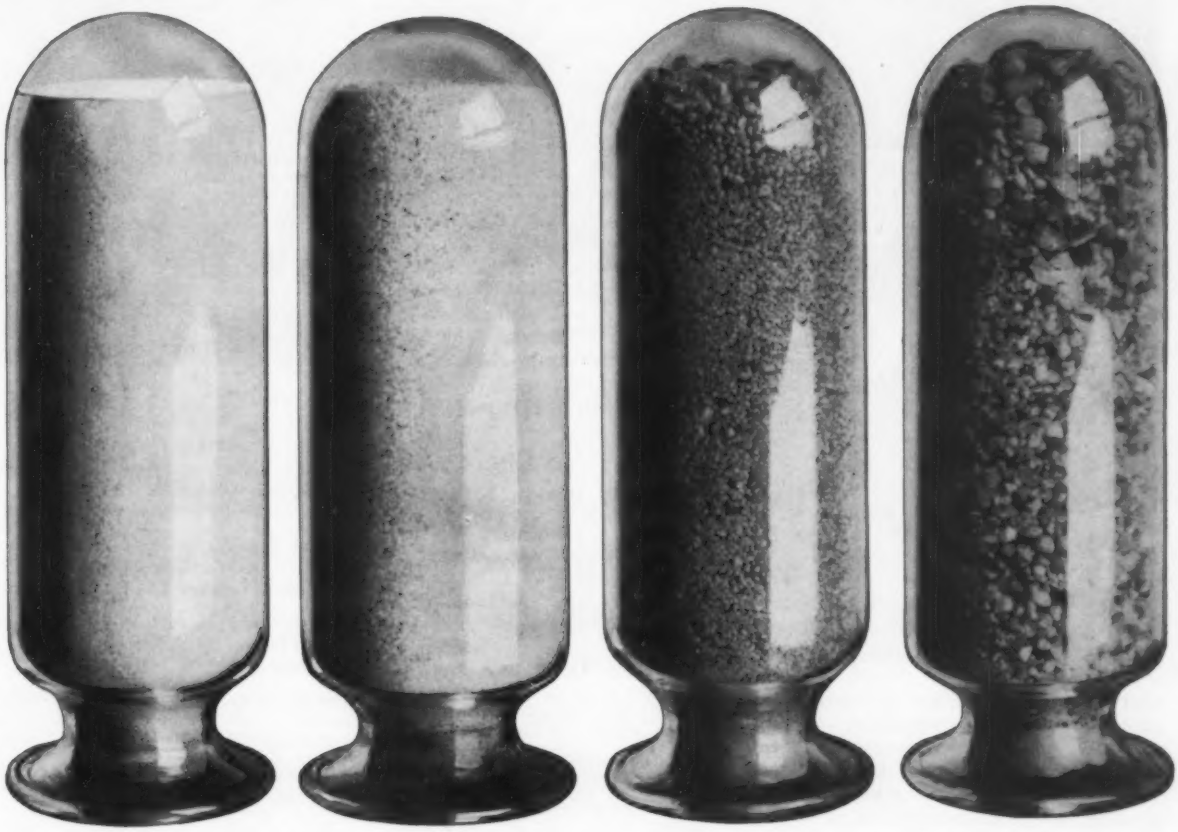
Cupola Melting Course Set For Chattanooga

Cupola Melting of Iron, co-sponsored by the AFS Tennessee Chapter and the AFS Training & Research Institute, will be given July 25-29 at the Patten Hotel, Chattanooga, Tenn. The course fee is $90.

This instructional course provides principles for cupola operation with emphasis on cost reduction. Subjects include raw materials, charging procedures, cupola design, combustion control, metallurgy of cast iron, maintenance, new developments and equipment, water-cooled, hot and cold blast operations.

Now Pennsylvania Glass Sand offers 35 grades of these foundry sands!



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Geauga Lake, Ohio • Jackson, Ohio • Phalanx, Ohio • Klondike, Mo. • Pacific, Mo. • Mill Creek, Okla.

Circle No. 152, Page 165

NORTHERN CALIFORNIA—Attending the April meeting were Philip Rodger, Vulcan Steel Foundry Co., Oakland, Calif., and Sam Russell Phoenix Iron Works, Oakland, Calif.

J. W. Smith, Oremet Co., Albany, Ore., spoke on vacuum casting of reactive metals. —by E. J. Ritelli

Northeastern Ohio Chapter

Conducts Simultaneous Sessions

"The best maintenance is always the cheapest maintenance," T. W. Harvey, Grabler Mfg. Co., Cleveland, told Cleveland area foundrymen at the March meeting. He emphasized that as the need for casting quality increases, the need for good maintenance grows in proportion.

Patternmakers heard Louis Schmidt, Aluminum Co. of America, Cleveland, outline the responsibility of producing a suitable tool. To provide the proper pattern, he needs information on the casting alloy, quantity of castings to be produced, tolerances, molding methods and foundry practices. He pointed out that plastic materials provide short cuts in reproduction of patterns, eliminate machining and simplify changes and repairs.

Principles of the CO_2 process in a non-ferrous foundry were outlined by W. A. Mader, Oberdorfer Foundries, Inc., Syracuse, N. Y. At Oberdorfer, 65 per cent of cores and molds are made by the CO_2 process. Nearly all cores used at Oswego, a permanent molding and die casting shop, are also made by the process. Sand used at both foundries is prepared at Oberdorfer with best results being obtained with a proprietary sodium silicate binder; occasionally, carbon or pitch additives are used.

—by Edwin Bremer, Robert H. Herrmann, Jack C. Miske

Washington Chapter

Honor Apprentice Winners

Winners in the chapter's apprentice contest were honored at the March meeting. Two of them received recognition in the AFS National Apprentice Contest.

Chapter winners were:

Wood Patternmaking—1st place, Wayne J. Bernhard, Puget Sound Naval Shipyard; 2d, Layne Whitmore, Pacific Car & Foundry Co.; 3d, George Manil, Peterson Pattern Works Co.

Steel Molding—1st, Gaile Canfield, Atlas Foundry & Machine Co., 2d, Marvin Owen, Atlas Foundry & Machine Co.; 3d, Kenneth Thompson, Atlas Foundry & Machine Co.

Non-Ferrous Molding—1st, Dennis M. Jennings, Puget Sound Naval Shipyard, (in the National contest he placed 3d); 2d, Gerald D. Rogers. Sunset Foundry Co.

Iron Molding—1st, Frederick Owen, Atlas Foundry & Machine Co.; 2d, Harold Christenson, Washington Iron Works; 3d, Malcom Snyder, Atlas Foundry & Machine Co., (3d place winner in the national iron molding competition); 4th, Carl W. Montz, Puget Sound Naval Shipyard. —by Hubert L. Rushfeldt

Cincinnati Chapter

Hears Casting Design Talk

Illustrations showing the application of good design were presented at the April meeting by J. B. Caine, consultant, Cincinnati. Caine emphasized the importance of good design, pointing out that this is a more important factor in gaining strength of cast parts than merely trying to increase the tensile strength of the metal.

Recognition was paid to members receiving AFS citations, faculty members and students from the University of Dayton, Universtiy of Cincinnati and the University of Kentucky.—by Stanley F. Levy

Twin City Chapter

Preventive Maintenance

"A balance between maintenance and lost production must be found," Robert C. Robinson, Central Foundry Div., GMC, Danville, Ill,, told foundrymen at the April meeting.

Robinson pointed out that if maintenance costs are very low, probably due to neglect, then production costs will be too high. On the other hand, to have no production losses, the maintenance cost would be prohibitive. At present, eight per cent of personnel at Robinson's plant are in maintenance with this percentage expected to increase with the trend to added mechanization.—by Matt Granlund

R. C. Robinson

BIRMINGHAM—T. W. Seaton, left, American Silica Sand Co., Ottawa, Ill., discussed sand segregation at the April meeting. E. C. Finch, right, American Cast Iron Pipe Co., served as technical chairman. —by Edwin Phelps

AFS Chapter Meetings

JUNE

British Columbia . . June 11 . . Birch Bay Country Club, Birch Bay, Wash. . . *Inter-Chapter Golf Tournament.*

Central Illinois . . June 11 . . 497th Engineers, Bessler's Lake, Groveland, Ill. . . *Annual Clambake and Barbecue Stag.*

Central New York . . June 18 . . Hinerwadel's Grove, North Syracuse, N. Y. . . *Clambake.*

Central Ohio . . June 4 . . Oak Park, Sunbury Road, Columbus, Ohio . . *Annual Picnic.*

Chesapeake . . June 11 . . Bowley's Quarters, Baltimore, Md. . . *Crab Feast.*

Cincinnati District . . June 13 . . Elks Country Club, Hamilton, Ohio . . *Annual Summer Outing.*

Connecticut . . June 17 . . Restland Farms, Northford, Conn. . . *Outing.*

Northeastern Ohio . . June 25 . . Brookside Country Club, Barberton, Ohio . . *Summer Stag Outing.*

Northern Illinois & Southern Wisconsin . . June 4 . . Morse Hills Country Club, Beloit, Wis. . . *Picnic.*

Oregon . . June 15 . . Park Heathman Hotel, Portland, Ore. . . *Plant Tour, Tektronix, Inc., Beaverton, Ore.*

Pittsburgh . . June 6 . . Churchill Valley Country Club, Churchill, Pa. . . *Annual Golf Party and Picnic.*

Saginaw Valley . . June 11 . . IMA Lodge, Potter's Lake, East of Davison, Mich. . . *Annual Picnic.*

Washington . . June 11 . . Birch Bay Country Club, Birch Bay, Wash. . . *Inter-Chapter Golf Tournament.*

Western New York . . June 18 . . Sturm's Grove, Buffalo, N. Y. . . *Annual Stag Outing.*

View of Gray Iron Pallet System. Pallets can be easily moved over rails by hand. Left: Plant Engineer Robert H. Clarke. Right: Scale mounted on fork truck weighs each component of charge.

ENGINEERING APPLICATIONS PAY OFF AT DALTON FOUNDRIES

INCREASED EFFICIENCY

To obtain faster, more efficient, production in the company's gray iron foundry, Robert H. Clarke, Plant Engineer at Dalton Foundries, Inc., Warsaw, Indiana, designed a pallet system. This flexible system allows molders to work two hours before pouring needs to begin. Cooling time can be varied to suit the job and pallets can be easily moved over rails by hand. No bottom boards are used and the handling formerly required to bring them back to the molders has been eliminated. The pallet system provides flexibility for both production and jobbing type work.

BETTER CONTROL

When bond and water are added to sand during mulling, the bond must be thoroughly combinded with water to be effective. Plant Engineer Clarke designed a system to pre-mix water and bond, and pump the mixture into a storage tank where it is stirred continually. From the storage tank, small amounts of the mixture are metered into a tank by a timer. Compressed air then blows this metered amount into the muller at the correct time. This system has resulted in better control of sand, faster mulling cycles, and easier handling of materials.

LOWER COST

At the Dalton Foundries the old wheelbarrow method used to charge the cupola required seven men. Clarke designed a scale which could be mounted on the front of a fork truck to weigh each component of the charge as it was loaded into a drop-bottom tub on the truck. After it is loaded, the fork truck delivers the material to the charging bucket. This simple, and inexpensive engineering change reduced the labor requirement to three men instead of the seven previously required.

You can help create a source of engineering talent for the foundry industry by participating in the FEF program as a contributing member.

Foundry Educational Foundation

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Space contributed by **Modern Castings** as another service to the metal castings industry.

Foundry Trade News

National Engineering Co. . . . Chicago, has started a year-long tour of principal foundry cities in the United States and Canada with its foundry caravan. The mobile sand-conditioning, handling and reclaiming plant is self-contained in a 37-ft trailer. Full-scale operating equipment is included for continuous sand preparation for molding or shell; cooling and elevating; pneumatic conveying, batch or continuous; and pneumatic sand reclamation. Each item may be operated separately or as a unit of the over-all system. A 15-min orientation talk is held prior to the demonstration.

National Malleable & Steel Castings Co. . . . Cleveland, and General Pacific Corp., San Francisco, have agreed to the sale of General Pacific's Hill, Hubbell Div. to National Malleable, subject to the approval of stockholders of General Pacific. The division has headquarters in Cleveland and plants in Youngstown and Lorain, Ohio; Hammond, Ind.; Denver, Colo.; and Napa, Calif. The company applies protection to steel pipe in the form of coatings, coatings-and-wrappings and inner linings to prevent corrosion.

Brass & Bronze Ingot Institute . . . Chicago, is conducting the "First Annual Brass & Bronze Casting Progress Awards," design to increase awareness of the new properties of various copper-base castings discovered through research at Battelle Memorial Institute. Deadline for entries is June 15. Two series of awards will be made: 1) a $500 award plus four other prizes for the best new use and 2) a $500 award and four other prizes for projected new uses.

Hamilton Foundry, Inc., . . . Hamilton, Ohio, is the new corporate name for Hamilton Foundry & Machine Co.

General Casting Corp. . . . Waukesha, Wis., is the new corporate name for General Malleable Corp. The new name was selected to conform to the actual service offered.

Albion Malleable Iron Co. . . . Albion, Mich., has acquired Muncie Malleable Foundry Co., Muncie, Ind. Shareholders of both corporations approved a merger that will boost Albion Malleable's productive capacity by 35 per cent. The Muncie foundry will function as a division.

Hyster Co. . . . with headquarters at Portland, Ore., has announced plans for construction of additional manufacturing and office facilities at Danville, Ill. The company's Danville Plant No. 2 will be enlarged by 115,000 sq ft to a total of approximately 225,000 sq ft. New construction will include a manufacturing addition of 95,000 sq ft and an office addition of 20,000 sq ft. Preliminary construction work has started with completion estimated about Oct., 1960.

Detroit Gray Iron & Steel Foundries, Inc. . . . New York, has announced plans for the construction of its new Shaw Process Division for manufacturing precision iron and steel dies and castings.

Woodruff & Edwards, Inc. . . . Elgin, Ill., has acquired **Richmond Foundry & Mfg. Co.,** Richmond, Va. The Richmond company will continue opera-

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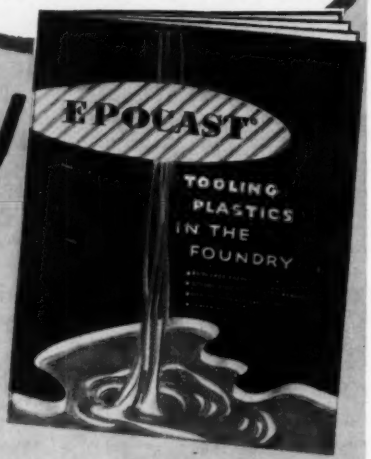

Describes Ten Major Pattern Applications

Eight big pages of technical facts, mixing proportions, curing data, pot life, results in application, coatings, release agents and new safety hardeners. Send for your free copy today.

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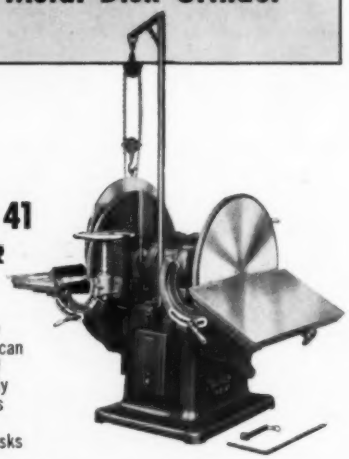
Circle No. 154, Page 165

Sturdy Sander for Pattern Shops Doubles as Metal Disk Grinder

"OLIVER" No. 41 SANDER



Here's a sturdy, soundly engineered sander that can handle a wide variety of pattern shop jobs quickly and efficiently. Base has wide flange for rigid support on floor. Two disks are 37½" in diameter, are made of steel plate finished all over and are balanced accurately. One man can change a disk. Sander has fine safety features. Tables are 46" long, 20" wide, have lateral adjustment of 2" and angular adjustment of 45 degrees. Send for folder giving complete technical details.

OLIVER MACHINERY COMPANY
GRAND RAPIDS 2, MICHIGAN

Circle No. 155, Page 165

tions under the present corporate name as a wholly owned subsidiary. George P. Edwards, president and chairman of Woodruff & Edwards is the new president of Richmond Foundry & Mfg. Co. J. Scott Parrish, Jr., former president, will pursue other business interests.

T. B. Wood's Sons Co. . . . Chambersburg, Pa., has completed construction of a new shell mold foundry to supplement existing facilities. Both cast iron and ductile iron are poured with castings ranging from one to 45 lb. The foundry is adjacent to the cupolas, minimizing heat loss in metal transfer. Workers are warmed with gas-fired radiant heaters suspended from the roof.

T. B. Wood's Sons Co. new shell mold foundry, Chambersburg, Pa.

Tatnall Measuring Systems Div. . . . and **Nuclear Systems Div.,** are now merged into the Instruments Div., Budd Co., Philadelphia. Offices will be at Phoenixville, Pa.

Crosby Foundry Sales Co. . . . Cleveland, has been appointed as Ohio sales representatives for Structra-Lung Co.

Nomad Equipment Corp. . . . Milwaukee, formerly operated as a division of Westover Corp., has been set up as a separate corporation with Oscar H. Kraft as president. The corporation, devoted to manufacture and sales of foundry equipment, is independent of the management firm.

Standard Refractories, Ltd. . . . Hamilton, Ontario, Can., has been named as a distributor for Walsh Refractories Corp., St. Louis, in the province of Ontario.

Massachusetts Institute of Technology . . . Cambridge, Mass., will sponsor a one-week course, Aug. 22-26, on engineering aspects of solidification of metals. The course will include theoretical lectures which will lead to practical examples of how the properties and reliability of castings can be enhanced by improved control over the solidification pattern of the casting. Among topics will be mechanism of solidification, heat transfer in metal and refractory molds, segregation and microporosity in ferrous and non-ferrous metals, vacuum melting, thermodynamics of metals, techniques for producing premium quality aluminum, magnesium and steel castings.

E. F. Houghton & Co. . . . Philadelphia, has opened a new plant in South San Francisco, Calif. Capacity has been increased more than 50 per cent over the former plant. It is located on a three-acre plot and includes 30,000 sq ft of manufacturing space, a new office building, control laboratory and 10,000 sq ft of outdoor storage area.

North American Refractories Co. . . . Cleveland, has announced the construction of a basic brick plant at Womelsdorf, Pa., scheduled for completion late this year. The plant will manufacture basic brick and specialty products.

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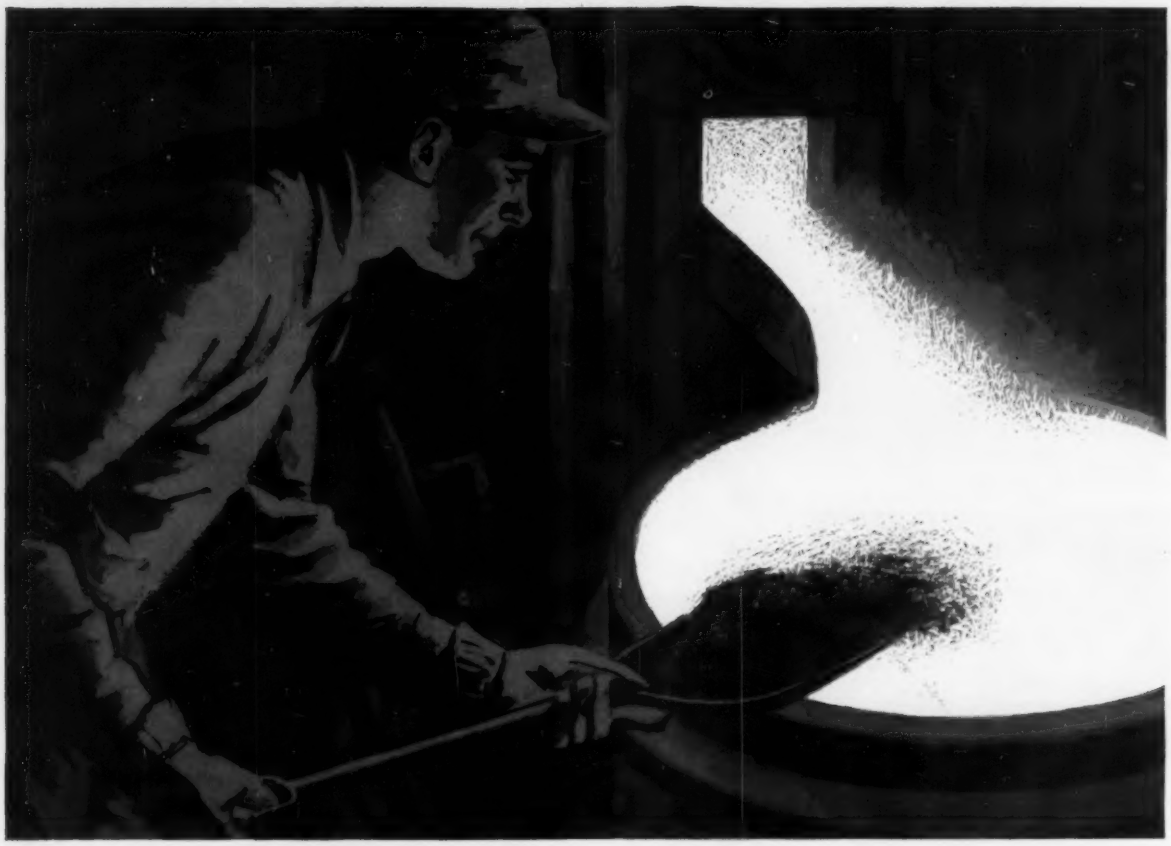
Circle No. 156, Page 165



dependable Molybdenum in the foundry

Primary justification for increased success in foundry applications of molybdenum is found in the dependability of results. Day after day the foundryman gets the results he needs by adding molybdenum to his melt. Molybdenum may be added to improve tensile and transverse strength, increase impact and fatigue strength, improve wear resistance, increase toughness and strength at higher temperatures, intensify effects of other alloying elements.

The consistency of results in production justifies confidence in MCA molybdenum.

MCA closely controls all of its manufacturing steps and the chemistry of its molybdenum products, hence the uniformity of results.

Complete stocks of molybdenum in all of its metallurgical forms are available through MCA. Technical assistance in meeting tough specifications or solving specialized problems is yours upon request. No obligation, of course.

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Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

MCA

Circle No. 157, Page 165

Spotlight on Products . . .

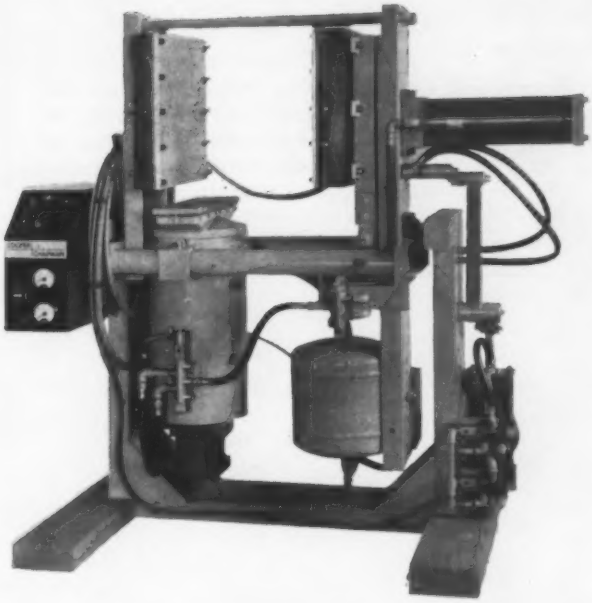
Equipment and processes featured at the AFS Exposition gave tools to foundrymen for meeting competition from other methods of fabrication. Many manufacturers used the five-day Show to announce new equipment and modifications.

Portable X-Ray Machine Permits On-The-Spot Checking of Castings

One man can carry this portable x-ray machine for quick, on-the-job inspection of any sized casting. Unit manufactured by Picker X-Ray Corp., is small enough to pass through a 6-in. opening but powerful enough to radiograph 1-1/2 in. steel.

Operates on practically any available power supply line and is reportedly twice as strong as conventional units of the same rating. Unit consists of a 50-lb generator and a 55-lb control.

For More Information, Circle No. 1, Page 165



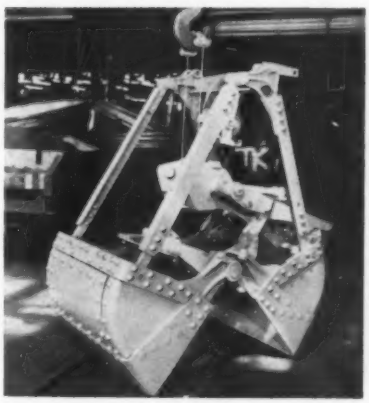
Automatic Shell Blowing Machine Has Completely Adjustable Cycle

Automation plus flexibility were designed into this new Canadian shell core blowing machines. Features push-button control which puts unit through a completely adjustable cycle for all types of shell cores.

Made in five sizes, it handles core boxes weighing up to 350 lb. Electrically heated plates range in size to 24 in. in height and 26 in. deep with cores up to 9 in. in diameter. Machine, manufactured by Cooper-Chapman, Ltd., operates at temperatures to 700 F and is designed for long runs with minimum maintenance. One operator can handle two or more machines.

For More Information, Circle No. 2, Page 165

Safety-Designed Clamshell Buckets Eliminate Many Handling Problems



Engineered for safety, the new Blaw-Knox clamshell buckets are designed to prevent accidental dumping, premature cable failure, damage to hoists and the hazards of hand injuries or lever kick-up. Automatic dumping may be performed when hazardous or inaccessible conditions make it desirable to relieve the floor attendant. Blaw-Knox Equipment Div., Blaw-Knox Co.

For More Information, Circle No. 3, Page 165

Continued on page 154

Products Spotlight . . .

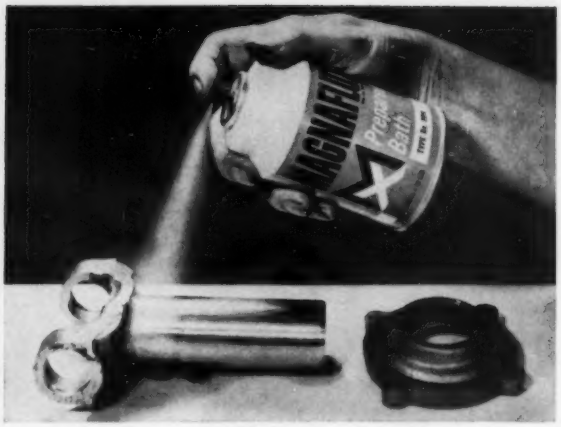
Continued from page 153

Easy-To-Use Spray Cans, Squeeze Bottles, Reduce Inspection Time

Faster and easier inspection now possible with ready-to-use pressurized spray cans and squeeze bottles for magnetic particle inspection. Displayed for the first time at the AFS Exposition by Magnaflux Corp., the materials can be used with any magnetic particle inspection equipment or test kits.

New containers eliminate previously bulky containers, problems of mixing to formula or filling application devices, and reduce set-up time.

For More Information, Circle No. 4, Page 165



Versatility of Carbon, Graphite Lead to Increased Refractory Use

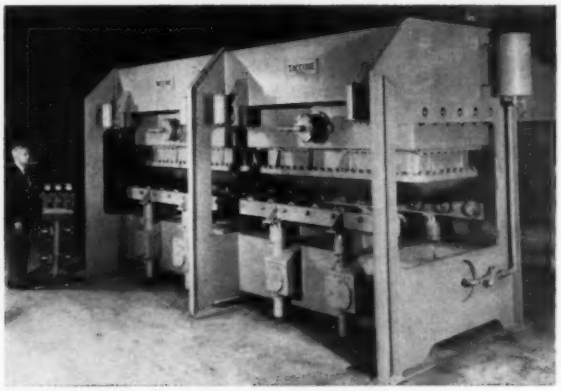
Carbon and graphite are fast proving their versatility as refractories wherever molten metals are handled in the foundry. National Carbon Co., Div. Union Carbide Co. demonstrated these capabilities by showing cupola linings, fluxing tubes for degassing, immersion bell assemblies for magnesium alloy addition, powders for injection, thermocouple parts and other products.

For More Information, Circle No. 6, Page 165

New Portable Liquid CO_2 Receiver Puts Constant Source On-The-Job

Store CO_2 indefinitely without loss. This new portable, 1000-lb liquid CO_2 receiver by Pure Carbon Div., Air Reduction Co., Inc., assures on-the-spot supply of low pressure liquid. Unit may be recharged by delivery truck. Receiver is completely self-contained with built-in controls, refrigerator, pressure gage and CO_2 weight indicator. Accessory 1000 watt, 120 v vaporizer available for supply vapor rates up to 25 lb per hr. Two or more vaporizers may be used for heavier flows.

For More Information, Circle No. 5, Page 165



Diaphragm Molding System Applies Equal Pressure on Entire Pattern

Speed, maximum mold hardness and uniformity of density are features of diaphragm molding with the Taccone Corp. machine. All variations of jolting, peening, ramming, tucking and butting are eliminated. All procedures may be preset.

Action of the diaphragm allows the handling of large and multiple molds as rapidly as small molds. Speed is limited only by the time of handling the flasks into and out of the machine.

Each flask gets the same pressure per sq in. of pattern regardless of size. The more complicated the pattern—the more efficient the squeeze.

For More Information, Circle No. 7, Page 165

Continued on page 156

Circle No. 125, Page 165

Precisely alloyed,
quality controlled, trouble-free:

FEDERATED "ENGINEERED" SILICON, ALUMINUM & MANGANESE BRONZES

For true-acting bronzes, specify Federated Herculoy Silicon Bronzes (excellent fluidity, tensile strengths up to 65,000 psi, yield strengths up to 35,000 psi); Aluminum Bronzes (tensile strength as high as 120,000 psi, after heat treatment); and Manganese Bronzes (as-cast tensile strength, up to 125,000 psi, exceptionally high hardness). Federated "Engineered" Bronzes are the end results of highly perfected production techniques and continuous quality control procedures developed by experienced metallurgists in Asarco's Central Research Laboratories. For complete data on Federated "Engineered" Bronzes, write or call: Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y., or your nearby Federated sales office.

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Montreal, P.Q., 1400 Norman St., Lachine, Phone: Melrose 7-3591

Circle No. 175, Page 165

Products Spotlight . . .

Continued from page 154

Deep Notches on Sectioned Ingot Provide Easier Handling, Melting

Speed ingot melting with unique 25-lb deep notched, four-section ingot. Deep-notched ingot, featured by the Metals Div., Olin Mathieson Chemical Corp., is easier to handle and break when alloying or melting in small crucibles.

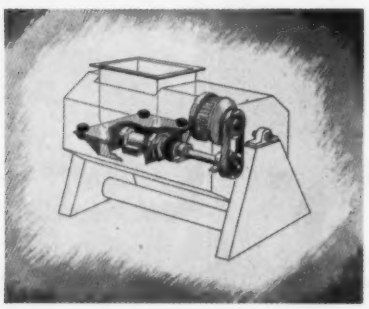
For More Information, Circle No. 8, Page 165

Pangborn Vibratory Finishing Unit Handles Wide Variety of Materials

Handle a wide variety of cleaning and finishing operations with a single machine. A 6-cu ft vibratory finishing machine by Pangborn Corp., performs cleaning, descaling, deburring, radiusing, fine polishing, coloring and burnishing of ferrous and non-ferrous metals.

Among features are an air-cushioned suspension which eliminates springs and an annular coupling to absorb shaft misalignment. The finishing machines come in 1-1/2, 3, 6, 12 and 18 cu ft models. Line includes accessories, auxiliary equipment and media and compounds.

For More Information, Circle No. 9, Page 165



Resin-Coated Sands

Increase mold and core production 50 per cent with resin-coated sands, a combination of a fast cure formula and the hot coating process developed by the Faskure Div., Aurora Metal Co. Sands give accurate control of shell thickness even though shell formation is rapid.

For More Information, Circle No. 10, Page 165

Sterling Extra Heavy Duty Flasks Designed for Large Metal Pourings

Equip for large metal pourings with extra-heavy duty foundry flasks featuring beefier flange construction, broader mating surfaces, more refinishing stock for every thickness of channel web. Flasks exhibited by Sterling National Industries, Inc., featured positive match, minimized deformation, high resistance to ramming shock and machine stress and improved stability.

For More Information, Circle No. 11, Page 165

Plastic Refractories Exhibit Volume Stability at Elevated Temperatures

Increase furnace operating efficiency with plastic refractories which exhibit volume stability at elevated temperatures. Photo shows two plastic refractories made by Harbison-Walker Refractories Co. and used in an electric furnace roof center application. One is a 70 per cent alumina plastic refractory and the other an 80 per cent alumina plastic refractory.

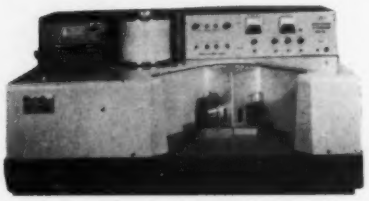
For More Information, Circle No. 12, Page 165

Spectrophotometer Design Permits Use of Accessories, Attachments

Cut spectrophotometer scanning time from 14 min to 4 min with new infrared double-beam recording unit exhibited at Exposition by Baird-Atomic, Inc. New automatic scan control and continuously accelerated speeds performs job with no loss of resolution or accuracy.

In addition, the design permits a variety of accessories which broaden its capabilities. The large sampling area permits easy use of accessories and attachments which include a 20-meter gas cell, ultra-micro liquid and gas cells and a micro-beam condensing system.

For More Information, Circle No. 13, Page 165



Two-Part Expendable Collapsible Pallet Box Is Easily Assembled

Simplify your pallet box system with a 5000-lb capacity, expendable, collapsible pallet box made of any size for handling, storing and shipping of castings.

The pallet box, by Bigelow-Garvey Lumber Co., is supplied in two parts—a box section consisting of four side walls and a collapsed flat and base pallet. The box is assembled to the base pallet by driving six nails.

For More Information, Circle No. 14, Page 165

New Books for You

Nondestructive Testing Handbook, Vol I and II . . . R. C. McMaster. The Ronald Press Co., New York. 1959. This compendium of nondestructive testing technology was prepared under auspices of the Society for Nondestructive Testing with a board of 106 contributing and consulting editors. The 54 chapters provide the knowledge needed to develop programs and solve the problems of modern industrial testing.

Machine Shop Operations and Setups, 2d Edition . . . H. W. Porter, C. H. Lawshe and O. D. Lascoe. 449 pp. American Technical Society, Chicago. 1960. This textbook is designed to meet the specific requirements of modern instruction in machine-shop techniques. Describes operation details on all important machine-shop tools. Also includes chapters on heat treating and machinability of many materials.

Annotated Equilibrium Diagrams of Some Aluminium Alloy Systems . . . H. W. L. Phillips. 86 pp. The Institute of Metals, London, England. 1959. Diagrams are reproduced for 20 binary aluminum alloy systems and 12 ternary systems. Each diagram is accompanied by comments and references.

Selected Methods of Analysis of Foundry Materials—Part 1, Pig Iron and Cast Iron . . . 97 pp. The British Cast Iron Research Association, Alvechurch, Birmingham, England. 1959. This manual was prepared as a practical guide to the chemist in the laboratory with no attention to theory. Chapters cover: sampling; determination of C, Si, Mn, S, P, Ni, Cr, Mo, Cu, Ti and Va; spectrophoto–metric determinations of certain elements; equipment, apparatus and reagents; and laboratory techniques.

Machine-Shop Estimating, 2d Edition . . . W. A. Nordhoff. 532 pp. McGraw-Hill Book Co., 327 W. 41st St., New York. 1960. This is a new edition of a manual designed to help readers estimate the time any machining job will take. All the machining operations performed in the average shop are covered, with a description of each machine and the work it does, data for making estimates of its operations and a sample estimate. Time values are given for every operational element, which the estimator may then combine to find total time for a specific job from setting up to completion.

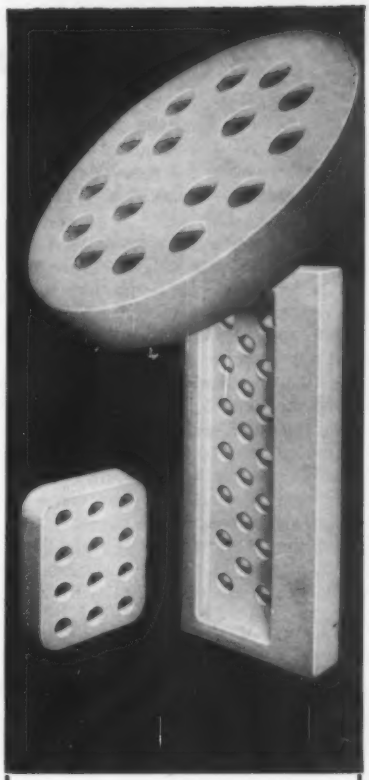
Fundamentals of Steel Foundry Sands . . . 152 pp. Steel Founders' Society of America, 606 Terminal Tower, Cleveland. 1959. A collection of six lectures presented at the Society's 1959 Technical & Operating conference: 1) Characteristics of Sand by J. F. Wallace; 2) Constitution and Significance of Clays and Bentonite by W. G. Lawrence; 3) Essentiality of Water Additions by W. D. Emmett; 4) Qualities of Organic Bonding Materials by V. E. Zang; 5) Mulling and Shaping of Molding Sands by J. A. Rassenfoss; and 6) Effect of Molten Steel on Sands and Molds by C. W. Briggs.

Malleable Iron Castings . . . 526 pp. Malleable Founders Society, Cleveland. 1960. A carefully prepared volume covering the following aspects of malleable iron—history, uses, physical properties, mechanical and engineering properties, pearlitic, alloying, designing, manufacturing, machining and metallurgy. Well indexed to make it easy to locate the answers to your problems.

Electrical Efficiency in Industrial Plants . . . Edwin S. Lincoln. 235 pp. F. W. Dodge Corp., 119 W. 40th St., New York. 1959. A practical engineering guide aimed at reducing electric power and lighting costs in industrial plants. Tells how to make surveys of load, power factor, voltage, lighting, wiring and electric protection. Full analysis of power costs is included with particular attention to methods of lowering rates by minimizing peak demands.

American Standard Safety Code for Head, Eye and Respiratory Protection . . . 46 pp. American Standards Association, 70 E. 45th St., New York. 1960. An important guide to use in protecting your employees in the foundry and other industries.

Photomicrography of Metals . . . 46 pp. Eastman Kodak Co., Rochester, N. Y. 1959. A new "how-to" book serves as a reference guide and review course for metallurgists. Contains sections on the metallographic microscope, illumination, filters in metallography, photographic materials, exposure determination, processing and printing.



Louthan strainer cores cut foundry costs

You minimize casting problems, get cleaner castings when you use Louthan *refractory* strainer cores. Now available in more sizes and shapes—and for steel, iron, brass and bronze castings. All provide an accurate choke for positive control of metal flow, eliminate slag and oxide inclusions.

Write for Free Gating and Risering Refractory Folder. Complete file of specifications on all Louthan products.

LOUTHAN

EAST LIVERPOOL, OHIO

A UNIT OF FERRO CORPORATION

Refractories Division

Circle No. 158, Page 165

How's Business...

The castings business for the last 12 months is way ahead of the previous 12 months. A look at the charts on this page and the next is ample proof.

The horizontal bars compare metal castings shipments for the 12 month period February 1958–January 1959 with the current period February 1959–January 1960. Looking at the individual metals you will see that gray iron is running 18 per cent ahead, malleable iron is up 38 per cent, steel–28 per cent, aluminum–28 per cent, copper–22 per cent, zinc–30 per cent. Only magnesium is behind, a mere two per cent.

Now let's look at the monthly rate of shipments shown in the right hand set of curves. Here the shipments for each month are compared with shipments for the same month in the year previous. When the curve is above the 100 per cent line, the industry is shipping more than last year, and vice versa.

All of the metals except magnesium have traced remarkably similar curves. Shipments rose during the first half of 1960 when they were well ahead of 1959. Then they leveled off in the summer and steadily declined during the last half of the year. Most of the metals reversed this trend in November and have displayed a new upward trend.

A recent communique from the Bureau of Census reveals that copper, aluminum, and zinc base casting shipments have continued upward in February. The biggest jumps occurred in die casting.

Business up

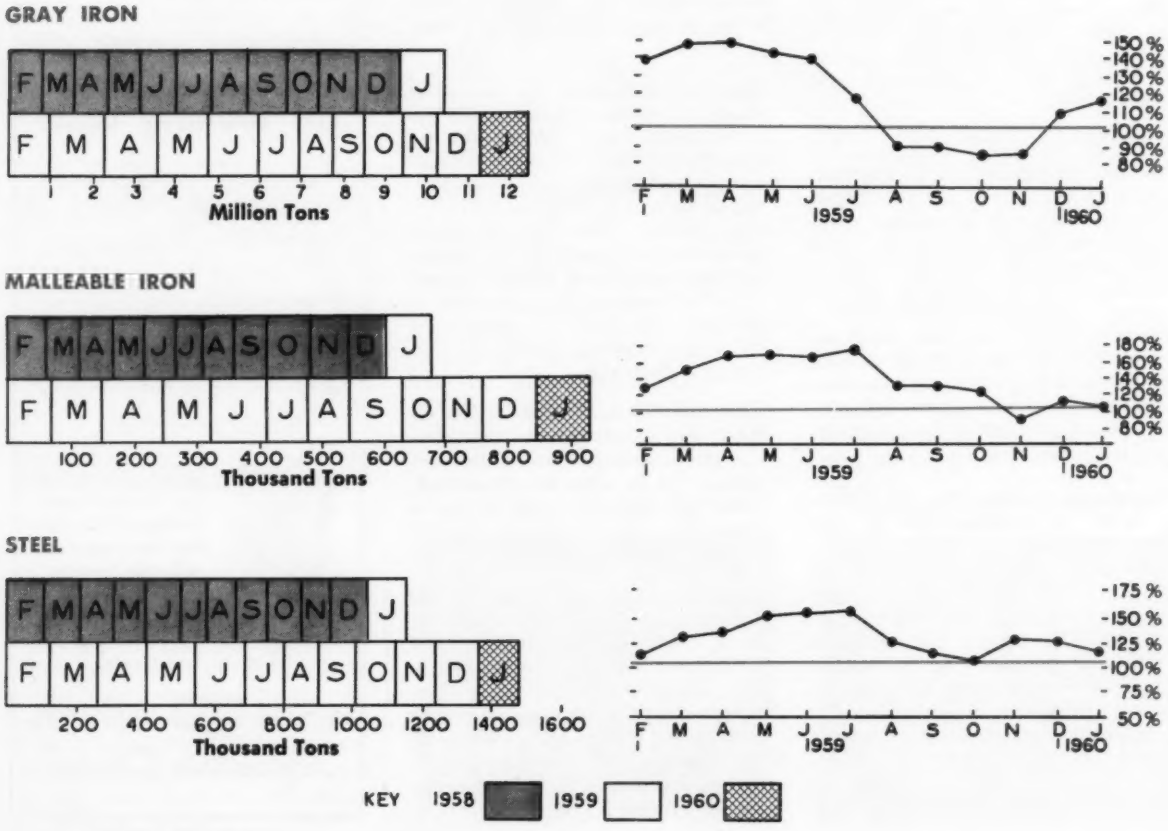
Auto makers reported retail sales gains in April. For the first four months this year Corvair sales are 75,396 and Falcons total 44,600 . . . National Machine Tool Builders Association reported orders for metal cutting tools totaled $49 million, up from $47.7 million for February. Strong order flow coming from foreign customers. March shipments were $10 million ahead of previous month. . . . National output of goods and services for first quarter of 1960 scored sharpest gain since third quarter of 1950. It reached a record seasonally adjusted annual rate of $498 billion.

Business down

For the eighth consecutive month construction awards dropped. March was 9 per cent below a year ago . . . Appliance output is being cut back by three big manufacturers . . . Commerce Department reported that man-

Trends in Metalcastings Shipments

Statistics from Bureau of the Census, U. S. Department of Commerce


GRAY IRON
F M A M J J A S O N D J
F M A M J J A S O N D J
1 2 3 4 5 6 7 8 9 10 11 12
Million Tons
150%
140%
130%
120%
110%
100%
90%
80%
F M A M J J A S O N D J
1959
1960
MALLEABLE IRON
F M A M J J A S O N D J
F M A M J J A S O N D J
100 200 300 400 500 600 700 800 900
Thousand Tons
180%
160%
140%
120%
100%
80%
F M A M J J A S O N D J
1959
1960
STEEL
F M A M J J A S O N D J
F M A M J J A S O N D J
200 400 600 800 1000 1200 1400 1600
Thousand Tons
175%
150%
125%
100%
75%
50%
F M A M J J A S O N D J
1959
1960
KEY 1958 1959 1960

ufacturers received $30.1 billion worth of new orders in March—down 1.6 per cent from February. Shipments dropped 2 per cent. Order backlogs slipped $800 million to $49.4 million. Inventories equalled the high established in 1957. . . . A Wall Street Journal survey of 389 companies shows that profits in the first quarter exceeded those of a year earlier but are likely to slip back to the 1959 level or lower in the second quarter.

Here and There . . .

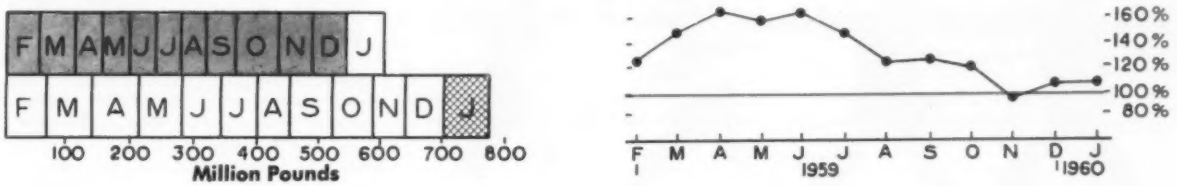
American Steel Foundries, Chicago, announced that, for the six months ending March 31, sales increased 21 per cent to $58,843,282 and earnings per share rose 44 per cent to $3,561,474. President Joseph B. Lanterman stated that in March the company shipped its first cast iron pressure pipe from a new plant in Council Bluffs, Iowa; moved into their new research laboratory in Bensonville, Ill.; and completed conversion of the East Chicago, Ind. plant from sand molding to shell molding.

National Malleable and Steel Castings Co., Cleveland, showed first quarter sales of $15,573,854, slightly higher than the first quarter of 1959. President Carter Kissell said, "Reductions in schedules of the automotive, truck, farm equipment, and road equipment industries are affecting sales of the Industrial Division." Based on present bookings, the second quarter should compare favorably with the first quarter.

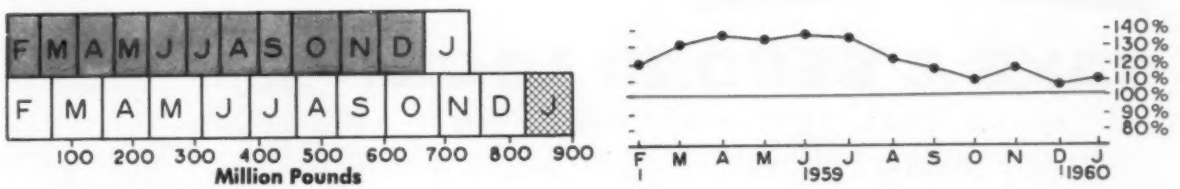
Traveling salesmen for the metal industries are driving more in 1960 to make sales than they did in 1959. Last years average for metal industry salesmen was 23,800 miles; projected average for '60 is about 25,000 miles. A. J. Schoen, president of Wheels, Inc., Chicago, says, "Salesmen report that increased competition accounts for upsurge in mileage driven . . . also, customers are tougher on price, demand speedier deliveries, and are more exacting in quality requirements."

Congressional action was urged to correct alleged abuses to the nation's aluminum smelting industry by Carl H. Burton, secretary of the Aluminum Smelters Research Institute. Burton asked that: 1) Exports of aluminum scrap be reduced and controlled as protection to the domestic industry which depends on scrap supplies as a source of raw material; 2) preferential discounts to "hot metal" die casting plants should not be permitted beyond actual savings to aluminum producers; and 3) legislation to increase import duty on aluminum pig to four cents a pound be defeated because it would place additional burdens on foundry customers.

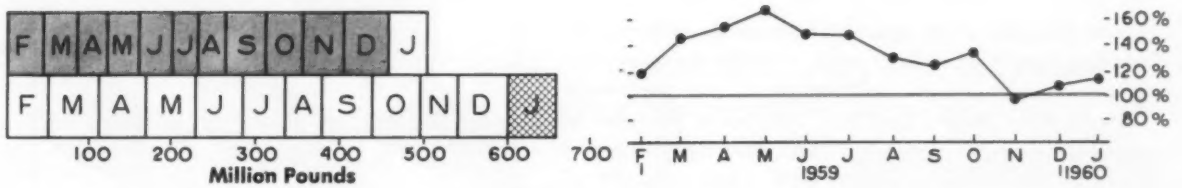
ALUMINUM



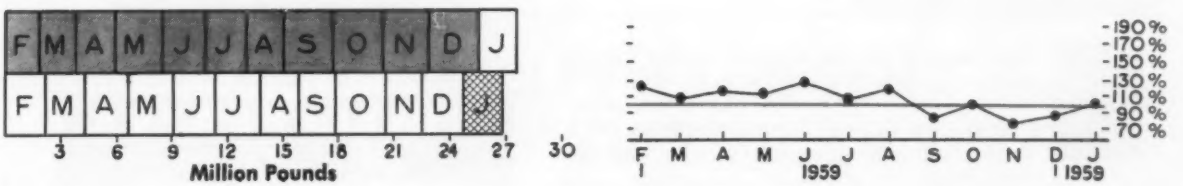
COPPER



ZINC



MAGNESIUM



Let's Get Personal

E. C. Klank

E. Shaw

S. W. Hughes

Edward C. Klank . . . formerly industrial sales engineer, Philadelphia Coke Co., Philadelphia, is now sales representative with Lancaster Foundry Supply Co., Lancaster, Pa. He will continue as publicity chairman for the Philadelphia Chapter.

Earl Shaw . . . has been named as foundry superintendent, Hale Fire Pump Co., Conshohocken, Pa., replacing **Sheldon Ward Hughes** who retired after 35 years service in the foundry industry.

Roy G. Heckenkamp . . . associated with Carondelet Foundry Co., St. Louis, since 1950, has been appointed treasurer. In addition to his present office he will serve as assistent secretary and office manager.

Richard G. Caulton . . . is now a sales engineer for Apex Smelting Co. with headquarters at the Cleveland plant. He was recently a manufacturers' representative in the Michigan area.

W. Turney Shute . . . formerly technical director of West Michigan Steel Foundry Co., Muskegon, Mich., and works manager of Canadian Steel Foundries, Ltd., Montreal, Canada, has joined Lester B. Knight & Associates, Chicago and is currently with the Knight Engineering Establishment in Zurich, Switzerland.

Dr. Henry J. Fisher . . . has been named manager, alloy development, Technical Div., The Beryllium Corp., Reading, Pa. Fisher joined Berylco from General Electric Co. where he was a research physical metallurgist.

Joseph L. Dow . . . district sales engineer for Elyria Foundry Div., Chromalloy Corp., has been transferred to Pittsburgh, Pa. He will be responsible for casting sales in Pennsylvania and the area east of the Hudson river.

W. G. Boyle . . . is now vice-president and general manager, General Metals Corp., Oakland, Calif. He was formerly associated with Pelton Water Wheel Co., San Francisco.

E. A. Sesnie . . . has assumed the duties of general manager, Metal and Alloy Div., Silver Creek Precision Corp., Buffalo, N. Y., succeeding **J. P. Bauer** who is retiring as manager but will continue as chief executive of the division. **Edward E. Miller** has been promoted to assistant general manager of the Metal and Alloy Div.

A. H. Ciaglia . . . G. E. Smith, Inc., Atco, N. J., was recently honored for his contributions by the Lions Clubs of New Jersey. In addition, he was recently cited for outstanding research and contribution to the plastics industry.

Henry J. Lang . . . has been named as sales representative for the state of Michigan by Acheson Colloids Co., Port Hur-

EXECUTIVE REPORT #17

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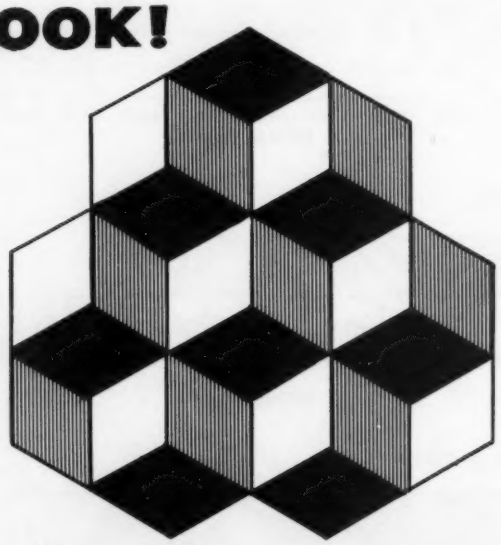
Count the cubes in the figure. You'll see six or seven, depending upon your point of view. Consider the total value of your present abrasive, and compare it with the proven value of Wheelabrator Steel Shot. Not just in price, but in abrasive consumption, cleaning speed, cleaning quality, and equipment maintenance costs as well. From any point of view, the proven quality of Wheelabrator Steel Shot adds up to extra value and extra profit.



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WHEELABRATOR
STEEL ABRASIVES

Circle No. 159, Page 165

on, Mich. He will headquarter in Detroit. Lang was formerly employed in the Philadelphia office of the same company.

George A. D'Andrea . . . formerly foundry superintendent, Arlington Bronze & Aluminum Corp., Baltimore, Md., has been elected vice-president and treasurer. He started with the company in 1950 and became a director in 1957. D'Andrea is currently a director of the AFS Chesapeake Chapter.

G. A. D'Andrea

N. J. Hynson

Norbert J. Hynson . . . formerly patternshop superintendent, Danko Pattern & Mfg. Co., Baltimore, Md., has been elected as vice-president and general manager. He began his patternmaking career with the company in 1941 and was elected a director in 1955.

Ray Krause . . . has been made vice-president in charge of engineering at Lester Castings, Inc., Bedford, Ohio. Krause joined Lester Castings in 1958.

William E. Karry . . . is now sales manager, Bay City Electric Steel Casting Co., Bay City, Mich. He was formerly sales manager, West Michigan Steel Foundry Co., Muskegon, Mich.

W. E. Karry

J. A. Madden

Joseph A. Madden, Jr. . . . has been named plant superintendent of Ephrata Mfg. Co., Ephrata, Pa. He was previously foundry manager, Burnham Corp., Lancaster, Pa.

Hiram Brown . . . has joined the staff of Battelle Memorial Institute, Columbus, Ohio, as consultant to the Department of Metallurgy. He was formerly technical advisor to the vice-president and general manager of the Solar Aircraft Corp., Des Moines, Iowa.

Ben R. Shipley . . . formerly assistant sales manager, has been promoted to

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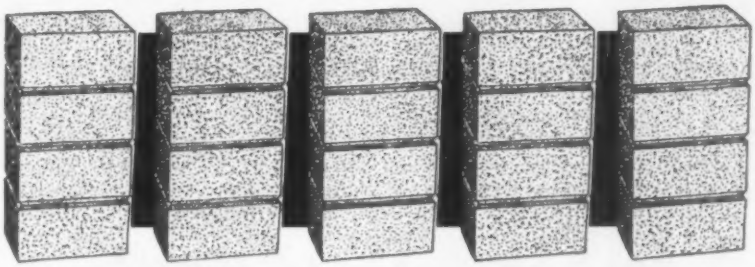
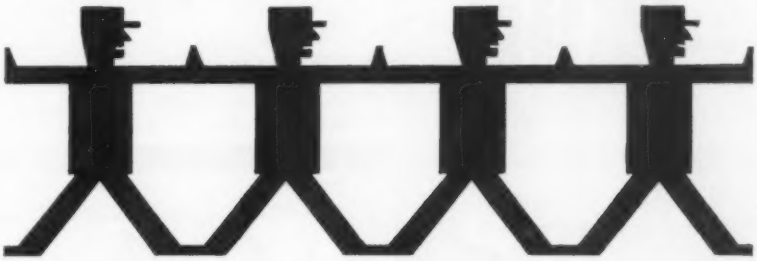


is consistent from brick to brick . . .



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We have no argument with those who sell for less . . . They know what their merchandise is worth!

If you melt aluminum, brass or copper, try Famous Cornell Aluminum, Brass and Copper Flux.

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Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes—Since 1918

Circle No. 160, Page 165

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Write for pattern requirements
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CMI

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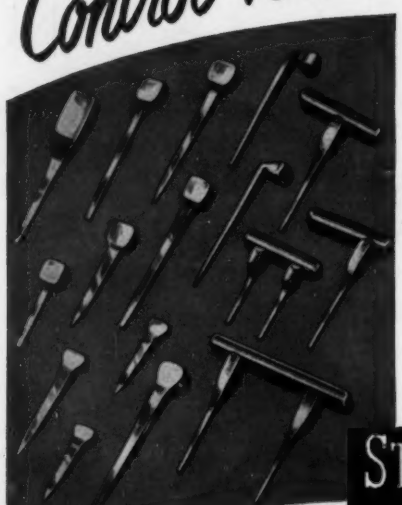
Plant: 20th Street & Hamilton Ave.
Racine, Wisconsin
Licensed under the Shaw Process

Circle No. 161, Page 165

Control Foundry Chilling with

CHILL KOOLHEAD NAILS



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Choose any style chill nail from jumbo to stubby; slim, medium, or horse nail blade; blunt, pointed, straight or 90° bent. Same types available in Stainless, Brass, Aluminum; Copper coated to order. Spider Chills, jumbo or horse nail legs—double or single. Available in various sizes and types; also made to your individual specifications.

Write for detailed descriptions and prices.

STANDARD HORSE NAIL CORP.
NEW BRIGHTON PA.

Other Products
STEEL Stanho PRODUCTS KEYS

Circle No. 162, Page 165

sales manager, Vesuvius Crucible Co., Swissvale, Pa. **Crawford B. Murton** has been named manager of marketing and development which includes market expansion, product planning and development.

Frank H. Dettore . . . has been elected a vice-president of G. E. Smith, Inc., Pittsburgh, Pa. He has been with the company for five years, recently as director of development.

F. H. Dettore

J. T. Hegner

John T. Hegner . . . is now president, Sterling National Industries, Inc., Milwaukee, succeeding **Richard A. Smith,** who is chairman of the board. Hegner is also a member of the board and treasurer. **Norman L. Schmeichel,** executive vice-president, is also secretary and **Melvin P. Pederson** is assistant secretary and treasurer.

James S. Vanick . . . research metallurgist with the Development and Research Div., International Nickel Co., has retired after 38 years service. Vanick has been active in many technical societies including AFS, having been awarded the AFS McFadden Gold Medal in 1956, served as chairman of the technical council, Gray Iron Division, and the Metropolitan Chapter.

Richard G. Whitlock . . . has been promoted to assistant sales manager, W. W. Sly Mfg. Co., Cleveland. He was previously engineering service manager.

R. G. Whitlock

J. R. Lampmann

James R. Lampman, Jr. . . . has been designated as sales representative for eastern foundry sales, Climax Molybdenum Co. Div., American Metal Climax, Inc., covering New England, New York, New Jersey and the southeast. He was formerly with Chapman Valve Mfg. Co. as a sales representative.

Charles F. Seelbach, Jr. . . . has been elected president and general manager,

Forest City Foundries Co., Cleveland. Other officers are: **Charles F. Seelbach, Sr.**, chairman of the board; **William F. Seelbach**, first vice-president; **Ralph G. Wieland**, second vice-president; **Walter Kremser**, secretary-treasurer.

Frank V. Jasienski . . . formerly operations manager, Albion Malleable Iron Co., Albion, Mich., has been named as

F. V. Jasienski

R. H. Dobbins

manager of the recently acquired Muncie, Ind., plant. **Richard H. Dobbins** has been named plant manager at the Albion operations.

Howard G. Monroe . . . Cuyahoga Falls, Ohio, has been named as assistant sales manager, Baroid Chemicals, Inc. In addition to retaining responsibility for sales in Ohio, Michigan and Indiana, he will assist in the training and guidance of the company's sales engineers.

Gordon L. Paul . . . formerly works manager, Hansell-Elcock Co., Chicago, is now foundry division manager, Brillion Iron Works, Brillion, Wis.

K. J. Kettner . . . formerly regional manager for northern Ohio and Michigan territories, Ramtite Co., Div., S. Obermayer Co., Chicago, has been named sales manager with headquarters in Chicago. **H. J. Shaner**, formerly Ramtite district manager of Chicago has been named to division manager, continuing to work out of Chicago.

W. D. McMillan . . . has joined Ohio Ferro-Alloys Corp., Canton, Ohio, as a foundry consultant. He recently retired from International Harvester Co. as a supervisor of metallurgy after 37 years service. He served as an AFS National Director and Chairman of the Chicago Chapter.

obituaries

Chesley A. Paul, 67, a Mathews Conveyor Co. executive, died in Ellwood City, Pa., on March 5. He started his career with the Mathews company in 1916, and retired in 1958 as vice-president in charge of purchasing.

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for AIRLESS BLAST CLEANING—PEENING. You are already paying for it—why not have it. Lowest in initial, operating and maintenance cost.

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3 cu. ft. $2375.00
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Complete with electrical equipment.

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WALKER PEENIMPAC MACHINE MFG. DIV.
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Circle No. 163, Page 165

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HAWLEY
Trav-L-Vent
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eliminates big, expensive area ventilating systems

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• *First and only* real solution to non-ferrous foundry ventilating problems. Eliminates "zinc shakes" and other health hazards . . . improves working conditions. Pays for itself in heat saved. *Installs at less* than ⅓ the cost of inefficient, conventional systems . . . uses as little as 1500 cfm. Will fit *your* foundry layout. Write now for complete information . . . or telephone 1300 in Wabash, Indiana.

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Circle No. 164, Page 165

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For The Asking

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Stress-rupture properties . . . of a super-alloy reportedly have been improved during course of 18-month development program. Read the results in 4-p brochure available for the asking. Wai Met Alloys Co.
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Master alloy . . . used for introduction of boron and titanium into aluminum alloys. Read about it in March, 1960 company publication. Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries, Inc.
For Your Copy, Circle No. 51, Page 165

Aircraft and missile . . . castings of aluminum and magnesium alloy must meet rigid specifications. Read about a foundry that meets the challenge in this MODERN CASTINGS reprint. American Foundrymen's Society.
For Your Copy, Circle No. 52, Page 165

Ventilation . . . of electric arc furnaces is discussed, and four methods analyzed in MODERN CASTINGS reprint. American Foundrymen's Society.
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Malleable iron . . . technical report discusses the metal in regard to its magnetic properties. Request this reprint from AFS TRANSACTIONS. American Foundrymen's Society.
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Hypereutectic . . . aluminum-silicon alloy is analyzed and properties presented in this AFS TRANSACTIONS reprint. American Foundrymen's Society.
For Your Copy, Circle No. 55, Page 165

Effect of tin . . . on flake and nodular graphite cast irons discussed in reprint from AFS TRANSACTIONS. American Foundrymen's Society.
For Your Copy, Circle No. 56, Page 165

Tooling plastics . . . technical bulletin outlines procedures for constructing core boxes, patterns, match plates, other foundry components. Furane Plastics, Inc.
For Your Copy, Circle No. 57, Page 165

Talks on tape . . . Metal casting technology in form of talks given before AFS meetings have been recorded and are available to you. For complete list and prices, use circle number below. American Foundrymen's Society.
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Electrodes . . . used with metal removal torches featured in folder. Arcair Co.
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Continued on page 167

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Individual elevated hard glass grinding surfaces are continually flushed with streams of water. This floats off the surface removal products, provides lubrication, and leaves sharp abrasive edges exposed at all times. A control valve permits complete selectivity of the volume of water. Ample drainage facilities with standard pipe fittings are provided at the rear. The grinding platforms are pitched downward and away from the operator.

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Buehler Ltd. METALLURGICAL APPARATUS

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4	16	28	40	52	64	76	88	100	112
5	17	29	41	53	65	77	89	101	113
6	18	30	42	54	66	78	90	102	114
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1	13	25	37	49	61	73	85	97	109		
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3	15	27	39	51	63	75	87	99	111		
4	16	28	40	52	64	76	88	100	112		
5	17	29	41	53	65	77	89	101	113		
6	18	30	42	54	66	78	90	102	114		
7	19	31	43	55	67	79	91	103	115		
8	20	32	44	56	68	80	92	104	116		
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Future Meetings and Exhibits

June 5-9 . . American Society of Mechanical Engineers, Summer Annual Meeting & Aviation Conference. Statler Hilton Hotel, Dallas, Texas.

June 6-8 . . Material Handling Institute, New England Show. Commonwealth Armory, Boston.

June 6-8 . . Malleable Founders Society, Annual Meeting. Elbow Beach Surf Club, Hamilton, Bermuda.

June 9-10 . . University of Wisconsin and AFS Wisconsin Chapter, Engineering Institute. War Memorial Center, Milwaukee.

June 14-17 . . Investment Casting Institute, Ceramics Course. Alfred University, Alfred, N. Y.

June 14-17 . . Cornell University, Industrial Engineering Seminar. Cornell University, Ithaca, N. Y.

June 16-17 . . AFS Chapter Officers Conference. AFS Headquarters, Des Plaines, Ill., and LaSalle Hotel, Chicago.

June 19-21 . . Alloy Casting Institute, Annual Meeting. The Homestead, Hot Springs, Va.

June 26-July 1 . . American Society for Testing Materials, Annual Meeting & Exhibit. Chalfonte-Haddon Hall, Atlantic City, N. J.

June 27-July 1 . . Gordon Research Conferences, Physical Metallurgy-Relation of Structure & Properties. Kimball Union Academy, Meriden, N. H.

Aug. 14-17 . . American Institute of Chemical Engineers and **American Society of Mechanical Engineers,** Heat Transfer Conference & Exhibit. Statler Hilton Hotel, Buffalo, N. Y.

Sept. 6-16 . . National Machine Tool Builders' Association, Machine Tool Exposition. International Amphitheatre, Chicago.

Sept. 14-15 . . American Die Casting Institute, Annual Meeting. Edgewater Beach Hotel, Chicago.

Sept. 19-24 . . International Foundry Congress. Zurich, Switzerland.

Sept. 22-23 . . National Foundry Association, Annual Meeting. Edgewater Beach Hotel, Chicago.

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Circle No. 168, Page 165

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A nationally known midwestern foundry has asked me to find a man capable of operating their non-ferrous foundry. They are interested in a man with both practical and technical knowledge, capable of producing a general jobbing line of aluminum brass and bronze, including pressure tight castings.

If your background runs along the above lines, I would appreciate your sending me a detailed resume including your salary requirement. **Box F-109, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

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FOUNDRY METALLURGIST—Graduate Engineer with experience in core and mold processes for technical service duties in Sales Department. Growth opportunity, some travel. Submit resume and salary requirements. **Cardox Division, Chemetron Corp., 840 No. Michigan, Chicago 11, Ill.**

FOUNDRY SUPERVISOR—Progressive modern non-ferrous foundry wants man capable of producing good results. Will be in charge of all foundry work. Must know all phases thoroughly—metal control, cores, molding, etc. Good opportunity for a good man. Located southeastern Wisconsin area. Replies confidential. **Box E-303, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

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Ultrasonic Vibrations Treat Aluminum Alloys

Here are the results of investigations into the structure and properties of aluminum and aluminum-based alloys resulting from treatment with ultrasonic vibrations using titanium alloy coupling rods or waveguides.

The molten metal was purposely saturated with moisture before observing the action of ultrasonics on degassing the melt. With a 22-lb melt, a method was developed for introducing ultrasonic vibrations into the melt enabling more complete degassing to be effected.

After treatment, a marked refinement of the as-cast structure was observed. Grain size of the metal treated with ultra-sound proved to be 1/30 to 1/40 of the initial grain size.

The experimental data show that ultrasonic vibrations eliminate from the melt not only visible gas occlusions but also microscopic gas bubbles. Moreover, the action of the field of vibrations is not confined to separate zones but it extends throughout the whole mass.

The condition of a metal coupling rod, immersed in a bath of molten aluminum at a temperature of 1330-1350 F under conditions of alternating loads of ultrasonic frequency, is such that the coupling rod gradually dissolves into the melt. This results from cavitation erosion and diffusion.

Evidently, the improvement in the mechanical properties is due to refinement of the grain fragments and enrichment of the grain with titanium.

Conclusions:

1. Ultrasonic vibrations are an effective means of cleansing aluminum alloys of gas inclusions.

2. The density and mechanical properties of castings are improved by treating the melt with ultrasonic vibrations before pouring into molds.

3. The treatment of melt with ultrasound enables the ultimate tensile stress and the yield point in particular to be improved under conditions of retarded cooling.

4. In treating a melt with ultrasonic vibrations, the melt absorbs the material of the coupling rod as a result of the erosive wear of the latter under the action of elastic vibrations and temperature. This phenomenon can be taken advantage of for inoculating aluminum alloys with high-melting metals.

Translated from Izv. Akad. Nauk SSSR, OTN, Metall. i Toplivo, May/June, 1959.

Condensed from a translation by H. Brutcher; circle No. 120, page 165, for a list of Brutcher Translations available for purchase.

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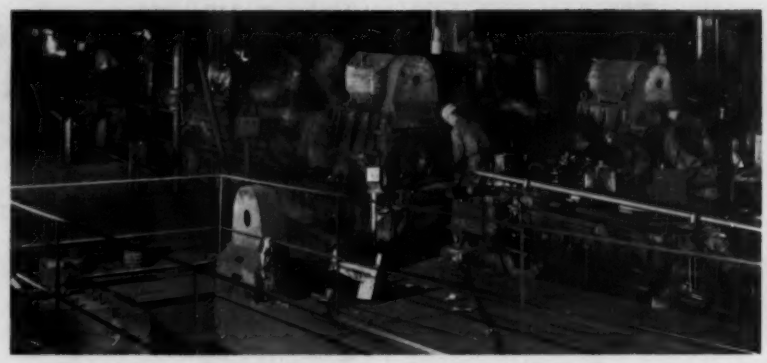


Centrifugally-cast, two-inch diameter pipe is now being produced for the first time by McWane Cast Iron Pipe Co., Birmingham, Ala.

Complete cycle of casting a pipe requires only two to three minutes.

Our June Cover . . .

CENTRIFUGAL CAST PIPE FOR UTILITIES

Centrifugal cast pipe for utilities . . . emphasizes the importance of our nation's iron pipe foundries—producers of the vital arteries which carry the water and gas throughout our modern cities.

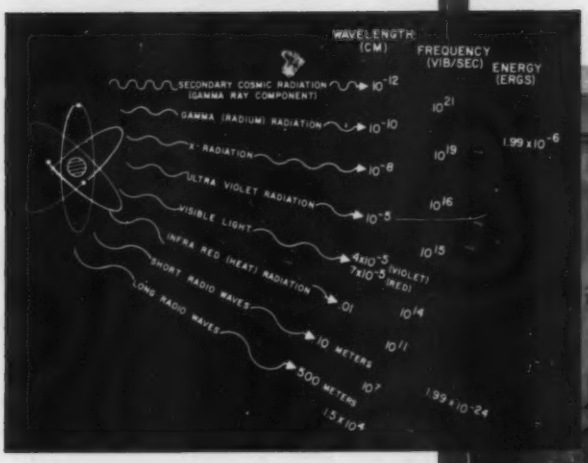
A particularly significant recent breakthrough in this industry has been the successful production of centrifugally cast, two-inch diameter, 20-foot long iron pipe by McWane Cast Iron Pipe Co., Birmingham, Ala. Two-inch pipe is used for water and gas service lines and small mains.

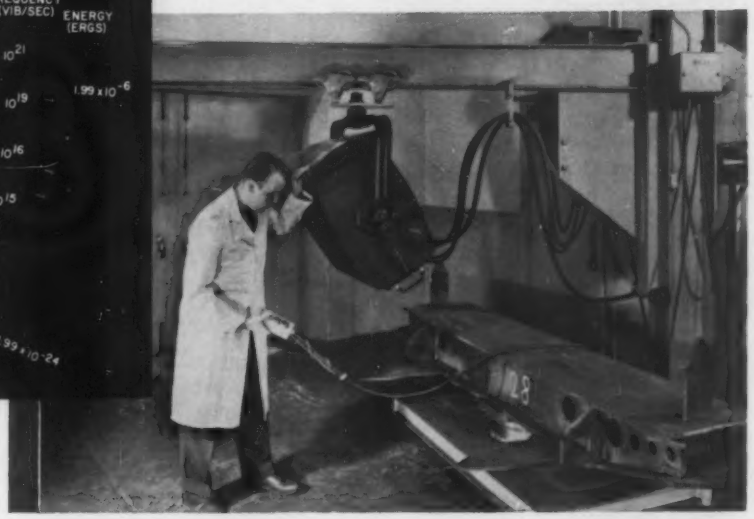
Top picture shows their equipment used in the deLavaud casting method which produces this small diameter pipe. A water-cooled metal mold with a down-hill inclination is spun at high speed while molten iron is poured down a long trough centered in the mold. First metal is introduced at the bell end (lower end). Machine gradually backs down inclined track so iron is distributed entire length of the pipe and around the periphery of the mold by centrifugal force.

Lower picture shows solidified, but white hot, pipe being withdrawn from the mold a few seconds after pouring. The complete cycle of casting a pipe requires only two to three minutes. Bell of the pipe is formed by a shell core. Pipes are rolled immediately into annealing oven where all casting strains are removed.

Recent figures just released by the Bureau of Census show that, in 1958, this mighty segment of the metalcasting industry shipped 2,084,458 tons of cast iron pressure pipe, soil pipe and fittings—valued at $315,914,000. A whopping 17 per cent of total gray iron shipments!

ARE YOU PROTECTED FROM RADIATION HAZARDS?





Greater industrial use of atomic energy and other forms of ionizing radiations make it necessary for industry to keep informed on their hazards, effects and plant control. Up-to-date information is essential on the possibilities of exposure to radiation, and understanding of how radiation can be handled safely is needed . . . especially among uninformed personnel.

"Foundry Radiation Protection Manual," published by the American Foundrymen's Society, explains radiation and its sources in foundry operations . . . how to detect and measure it . . . protective means to minimize medico-legal entanglements . . . and how to provide a sound engineering foundation for complying with safety requirements.

Here is a wealth of information covering a wide range of radiation origins, including the commonplace X-ray source. Subject matter details radiation . . . where it exists . . . why controls are necessary, what controls are available, how to apply them.

While the book concentrates on radiation as it pertains to the foundry industry, it has broad application for other fields where workers come in contact with radiation sources.

CHAPTERS INCLUDE

- Nature and Source of Radiation
- Health Aspects
- Control of Radiation
- Detection Instrumentation
- Protection by Time, Distance and Shielding
- Protection in Handling and Use

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The Editor's Report

by Jack Schrum

Perhaps . . . you were not able to attend the 64th AFS Castings Congress in Philadelphia, May 9-13. Or perhaps you did attend and discovered it was impossible to take in all the technical sessions, symposiums, luncheons and shop courses. In either situation you will want to keep up with the new technology by reading the count-down which appears on page 29.

These interpretive comments came for the most part from the men who served as Chairmen of the Program & Papers Committees of the various AFS Technical Divisions and Committees. In this capacity they were responsible for planning the technical program just presented in Philadelphia. Combine this qualification with the broad experiences of these men in the metalcasting industry and you have the background so necessary for evaluating this tremendous compendium of material unveiled at the AFS Congress.

Distilled from over 600 pages of printed text, this summary is divided into 16 major areas of technical interest.

Woven fiber glass screen . . . is a new arrival in the foundry industry. Place it in gates to clean dirt from non-ferrous metal. Located near point of contact between riser or sprue and casting, it facilitates removal. Easily cut with scissors, the screen does not in any way contaminate the melt when returned to the furnace.

Don't throw away your old firebricks . . . pulverize them in a tumbling barrel . . . mix with fire clay and water and you have a good refractory patching material for furnaces and ladles.

Office of Assistant Secretary of Commerce for Science and Technology . . . in the Federal Government has been recommended by a Special Advisory Committee of the National Academy of Sciences. "Science and technology," the Committee asserts, "are playing an increasingly larger part in the industrial and business activities of the nation." Secretary of Commerce Frederick H. Mueller has given instructions to initiate prompt measures for appraisal of the report and to propose plans for a course of appropriate implementation. Well, maybe some help for the research-starved foundry industry is on its way!

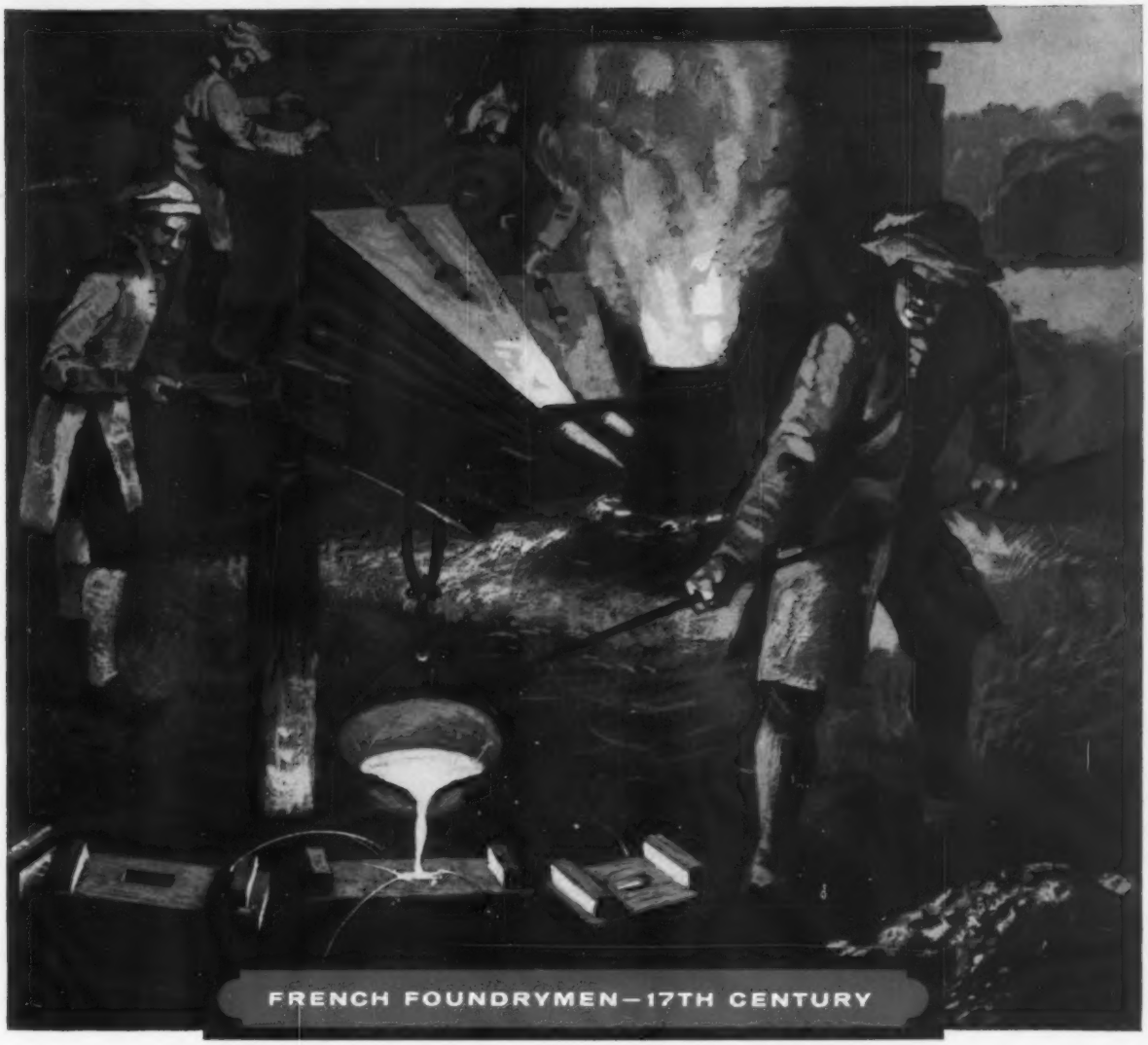
Inventions wanted by the armed forces . . . have been carefully described in a new publication by the National Inventors Council. Wonder what's needed in the way of metals? Here are a few: Ductile Silicon—because of its corrosion resistance, infrared transparency, high hardness, thermal shock resistance and inverse thermal coefficient of expansion. Protective Coating for Magnesium—to improve its corrosion resistance in marine atmospheres. Light Metals and Alloys—with a 30 million psi elastic modulus and ductility, elastic limit and tensile strength approaching structural alloy steels. If none of these suit your inventive genius there are several hundred more described in the booklet.

No sign of wear or fatigue . . . is visible on an epoxy plastic reinforced pattern after 950,000 severe jolts on a 6000-lb jolt, rollover, draw molding machine. This production pattern measures 40 x 40 x 2.5 in. and has been in continuous service for three and a half years at Weil-McLain Co., Michigan City, Ind.

Shotgun wedding . . . of two competitive processes—casting and welding. If casting is too big or too complicated, break it up into easily castable segments. Then weld them together. The cast-weld approach is becoming popular in the steel foundry industry. Solves a lot of rigging problems and often makes it easier to achieve higher casting quality standards.

Zircon sand . . . although more expensive than silica sand, is paying its way by reducing high labor costs in the cleaning room. Trouble spots on castings where burn-in is severe can usually be eliminated with local application of zircon facing. Zircon cores similarly resist burn-in and facilitate casting cleaning. High conductivity of zircon has led to its use as a mild chill for speeding metal solidification. Some foundries are even going to an entirely zircon sand system. Pacific Alloy uses an all-zircon mold for casting steel aircraft rudder actuators, and John Deere Tractor Works makes aluminum connecting rods for tractors in zircon molds. Because of its high density, zircon sand can be reclaimed from silica sand at a nominal expense.

Gray Iron Foundry Milestones—No. 3



FRENCH FOUNDRYMEN—17TH CENTURY

IN THE 16th and 17th Centuries, Central Europe made tremendous strides in the use of iron, a cast metal relatively new to the Continent. Prior to this era, iron had been referred to as a "base" or "corrupted" metal, with the more attractive bronze and brass in greater favor.

In spite of this prejudice, cast iron had demonstrated its usefulness and serviceability in the forms of firebacks, tombstones, weights, anvils, cannon balls and similar items.

Development of the stove played a major role in the acceptance of cast iron, and before 1800 stove-making had become the "most extensive, superb and profitable manufactures" in Europe and America.

Today, as a supplier of quality foundry coke and pig iron, Pittsburgh Coke & Chemical Co. is proud to contribute to the continuing growth of the Gray Iron Foundry Industry.

Reproductions of the "French Foundrymen 17th Century," suitable for framing, may be obtained without charge by writing to the Coke & Iron Division, Pittsburgh Coke & Chemical Company, Grant Building, Pittsburgh 19, Pa.

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1563

Neville Pig Iron and Neville Coke for the Foundry Trade

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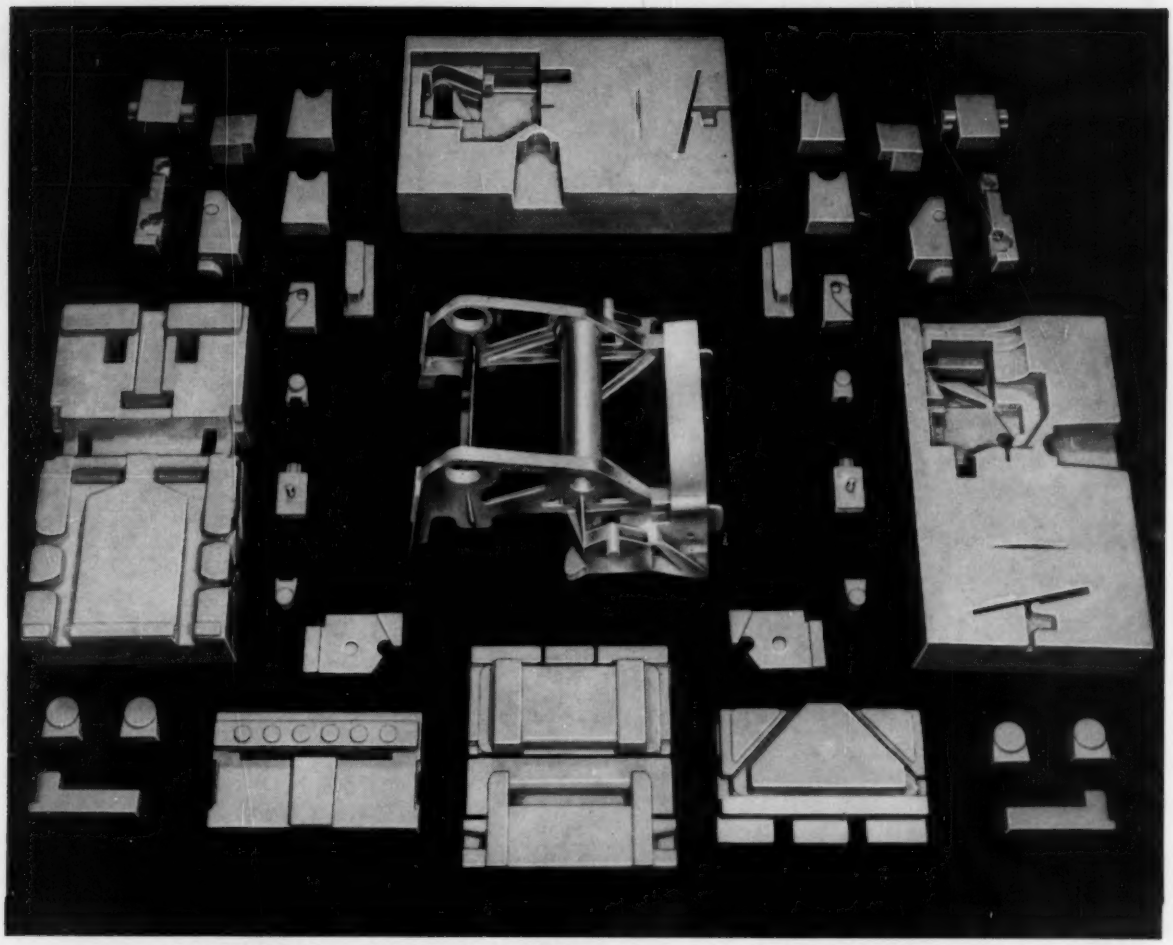

How RCI FOUNDREZ CORE BINDER Helped AMERICAN BRAKE SHOE Meet MIL-C-21180A

To produce the strong, dimensionally precise, lightweight casting shown above, the Light Metals Department of American Brake Shoe Company in Mahwah, New Jersey called upon two of the latest advances in metalworking technology . . . Ductaluminum, a relatively new and stronger aluminum alloy and RCI's FOUNDREZ liquid amino-aldehyde core binder. Used together, they now make it possible for foundries to meet military specifications in castings of this complex nature. ■ Thirty-six individual cores (see illustration) are required to produce this jet canopy casting. And why does American Brake Shoe choose RCI FOUNDREZ for this application? Four factors are involved: **1.** *RCI's liquid amino-aldehyde core binder provides better binder distribution in the core sand which contributes to exact casting dimensions and keeps surface defects at a minimum.* **2.** *The advantage of dielectric baking, and the high core strength obtained, increases core production and speeds core handling.* **3.** *Excellent core knockout and collapse qualities, at the lower pouring temperatures of aluminum, speed production and reduce the cost of finishing.* **4.** *RCI's reputation for on-time delivery and prompt technical service.* ■ If you are pouring metal castings at temperatures below 2700° F, we suggest you investigate the improved core properties offered by RCI's FOUNDREZ liquid amino-aldehyde binder. Reichhold will deliver this unique resin to you from seven convenient shipping points in tank cars, tank trucks or drums. Write today for Technical Bulletin F-2-R for full data on RCI's FOUNDREZ 7600 series.

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